SOUTH CAROLINA WATER PLAN 2003

South Carolina Department of Natural Resources

Land, Water and Conservation Division

2221 Devine Street, Suite 222

Columbia, SC 29205

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INTRODUCTION

The South Carolina Water Resources Planning and Coordination Act of 1967 assigned the overall responsibility for developing a comprehensive water resources policy for the State, including coordination of policies and activities among State departments and agencies, to the South Carolina Water Resources Commission. As part of government restructuring, this act was amended in 1993, and these responsibilities were placed with the South Carolina Department of Natural Resources (DNR).

The water resources policy plan consists of two parts. Phase I—an assessment of the water resources of the State—was published as Water Resources Commission Report No. 140, *South Carolina State Water Assessment*. The *Assessment* describes the State's stream, lake, and aquifer systems and provides information relating to the occurrence and availability of water in South Carolina. Phase II outlines guidelines and procedures for managing the State's water resources, and was first published in 1998 by the Department of Natural Resources as the *South Carolina Water Plan*.

Both the *Assessment* and the *Water Plan* must be updated periodically, on the basis of changes in water demand and availability, and on development of new technologies and management strategies. The updating of the *State Water Assessment* is underway. This second edition of the *South Carolina Water Plan* includes experience and knowledge gained from the severe drought of 1998-2002.

PURPOSE

The purpose of this *Water Plan* is to establish guidelines and procedures for the effective management of the State's water resources to sustain the availability of water for present and future use, to protect public health and natural systems, and to enhance the quality of life for all citizens.

The *South Carolina Water Plan* outlines procedures for assuring that future water requirements of the State can be met and acknowledges that (1) South Carolina usually possesses an abundance of water; (2) water is a limited natural resource and is a major factor for present and future economic development; (3) there are regional and temporal variations in the amount of available water and in the demand for water; and (4) there are both intrastate and interstate competing demands for water. The *Water Plan* discusses the source, availability, and quality of the State's water, as well as the demands for that water. It also outlines procedures by which (1) an accurate inventory of water withdrawn, stored, and discharged will be maintained; and (2) conflicting demands for water and damage to the natural resources will be minimized, especially during periods of water shortage.

LEGAL STATUS OF WATER IN SOUTH CAROLINA

The Supreme Court of South Carolina has established that water is subject to the Public Trust Doctrine and is, therefore, too important to be owned by one person.

> "The underlying premise of the Public Trust Doctrine is that some things are considered too important to society to be owned by one person. Traditionally, these things have included natural resources such as air, water ...and land.... Under this doctrine everyone has the right to breathe clean air; to drink safe water; ... and to land on the seashores and riverbanks." [Sierra Club v. Kiawah Resort Assoc., 318 S.C. 119, 456 S.E.2d 397 (1995)]

South Carolina abides by the Riparian Rights Doctrine and incorporates the concept of reasonable use of water in the Riparian Rights Doctrine. The Riparian Rights Doctrine holds that it is a fundamental right of any riparian landowner to the "reasonable use" of water [White v. Whitney Mfg Co., 60 S.C. 254, 38 S.E. 456 (1901)]. The difficulty with water management is that any limitation the State might place on riparian rights could be challenged in court as a "taking." However, there is legal precedent that the State has authority to manage water without compensating adversely affected riparians. In Rice Hope Plantation v. South Carolina Public Service Authority [216 S.C. 500, 59 S.E.2d 132 (1950)], the court said that the waters of the State are part of the public domain and the State may authorize the diversion of such waters for any purpose it deems advantageous to the public, without providing compensation to the riparian proprietors injuriously affected. Such a diversion is not a taking of private property by eminent domain, but a disposition by the public of the public property.

WATER RESOURCES MANAGEMENT GOALS

In recognition that the State's waters are part of the public domain, and are to be managed in the best interest of the public, the following are declared to be the water resources management goals of South Carolina:

1. To ensure that water of suitable quality and quantity is available for use when and where needed.
2. To manage the quantity and quality of both surface and ground water in an integrated manner to protect, maintain, and enhance the overall resource.
3. To use the *South Carolina Water Plan* to provide guidance for regional and local water planning efforts.
4. To develop interstate agreements with North Carolina and Georgia for the protection of water quality and quantity and for equitable allocation of surface and ground water.
5. To allocate surface and ground water equitably. During water shortages, all users should share the burden.
6. To have a drought management and mitigation plan that establishes actions and procedures during different drought levels.
7. To have a flood management and mitigation plan that establishes actions and procedures to minimize flood hazards and protect life and property.
8. To protect freshwater and estuarine ecological functions and habitats.
9. To regulate interbasin water transfers in a way that reflects the variability in water availability, respects the natural systems, and protects the source basin's present and future water demands.
10. To utilize advanced technologies, procedures, and practices to promote efficient use of water and to meet present and future water demands.
11. To develop a water-conservation ethic by providing educational opportunities and information to the citizenry.
12. To maximize the use of wastewater as an alternative to freshwater.

Some of these goals are already being addressed with existing programs; other goals have yet to be given appropriate attention. All of these goals, however, represent important steps toward the ultimate goal of protecting the State's waters so that this vital resource will be available for the use and benefit of all future generations.

SOUTH CAROLINA'S WATER RESOURCES

Although South Carolina has an abundance of clean, fresh water, it is unevenly distributed in both location and time. Almost all of the State's water is ground water, located beneath the land surface; only about one percent of the State's water is surface water. Most of the ground water is located in the Coastal Plain province, and most of the surface water is located in large, man-made reservoirs on the major rivers. Water is most abundant during the spring months when stream flows and ground-water levels are at their highest; less water is available during the late summer and early fall, when flows and ground-water levels are typically at their lowest.

Although there is much more water under the ground, surface water is the source for most of the water supplies in the State because of its convenience and availability.

HYDROLOGIC SETTING

The State's physiographic and climatic settings are key factors that determine the availability and distribution of the State's water resources.

South Carolina contains all or part of four major river basins (Figure 1). These major watersheds, defined by the topography that controls surface water drainage, can be divided into sub-basins based upon local drainage patterns. The two largest of these basins, the Yadkin-Pee Dee and the Catawba-Santee, encompass about 25 percent and 34 percent of South Carolina's area, respectively, are shared with North Carolina. The headwaters of most of the major rivers in these two basins are located in North Carolina. The Savannah Basin encompasses about 15 percent of the State and is evenly shared with Georgia, with a small area at its northern tip located in North Carolina. The ACE (Ashepoo-Combahee–Edisto) Basin, which covers about 26 percent of the State, is the only major basin located entirely within South Carolina.

In South Carolina, the four major basins are divided into 15 major sub-basins, and these sub-basins can be further divided into smaller local watersheds. In fact, the United States Geological Survey (USGS) has delineated more than 1,000 sub-watersheds in South Carolina (Bower and others, 1999).

South Carolina contains parts of three major physiographic provinces that extend throughout the southeastern United States (Figure 2). These provinces—the Blue Ridge, Piedmont, and Coastal Plain—are defined on the basis of physical geography and geology. The boundary between the Blue Ridge and Piedmont is defined by a sharp change in topographic slope at an elevation of about 1,000 feet, but from a water resources perspective, the Piedmont and Blue Ridge provinces are essentially the same. The boundary between the Piedmont and Coastal Plain, called the Fall Line, is defined as the surface contact between the metamorphic rocks of the Piedmont and the unconsolidated sediments of the Coastal Plain.

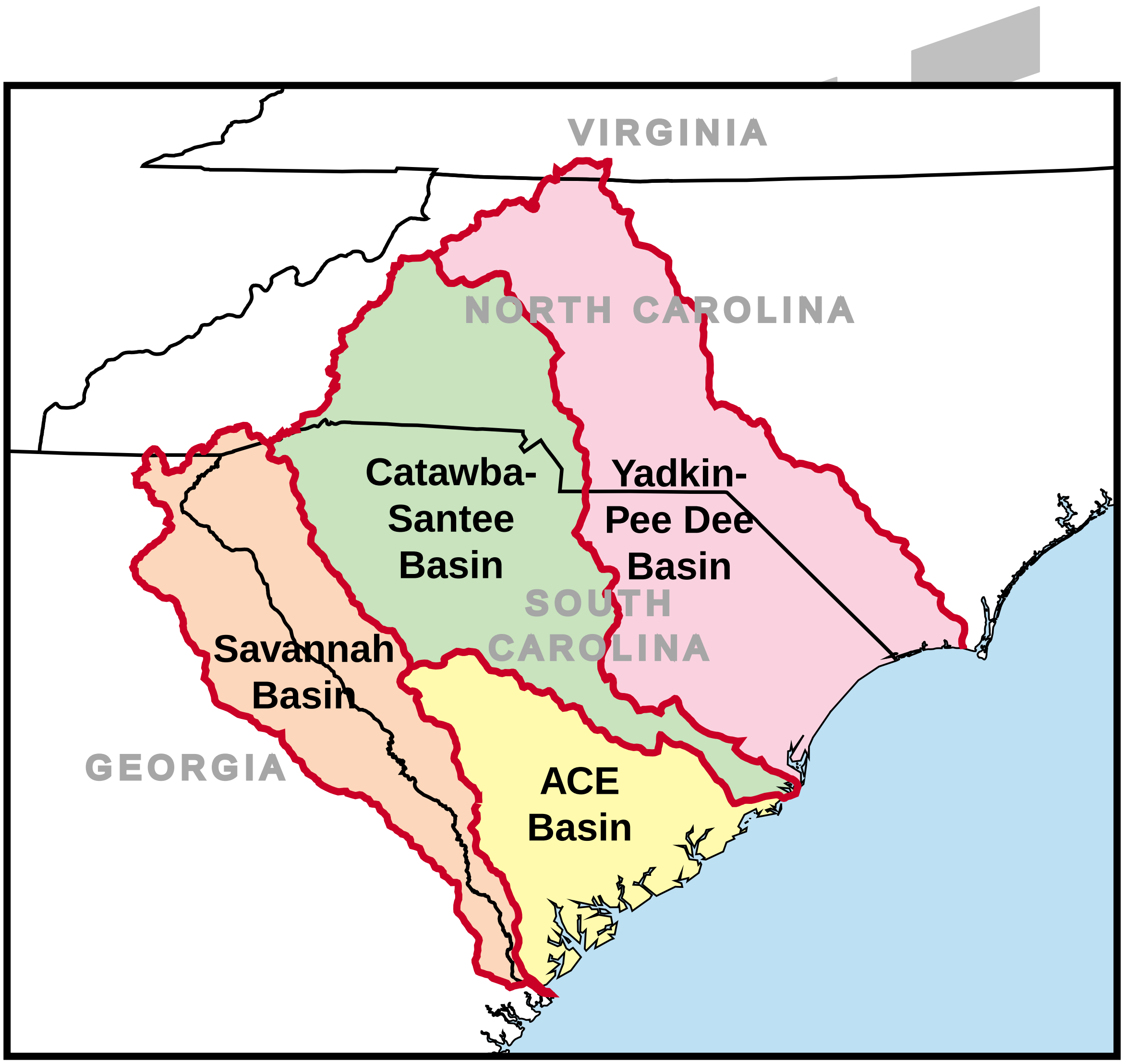


Figure 1. Major hydrologic basins in South Carolina. The ACE Basin is the Ashepoo-Edisto-Combahee Basin.

Within the Coastal Plain, which encompasses about two-thirds of the State, sediments overlie basement rock (or "bedrock"), thickening from just a few feet near the Fall Line to about 3,800 feet at the southernmost corner of the State (Figures 3 and 4). These sediments form the aquifers that hold most of the State's water. Aquifers—extensive, continuous beds of sand or limestone generally bounded above and below by impermeable clay layers—hold water in the pore spaces between sand grains or in voids within the limestone rock. Water enters an aquifer primarily near its outcrop area, where the sediments are at or very near to the surface. In this recharge area, precipitation and surface water slowly seep into the permeable sediments to replace water removed from the aquifer elsewhere. The storage capacity of these aquifers is great: about 95 percent of the State's total volume of ground water is contained in the Coastal Plain aquifers (Newcome, 1989).

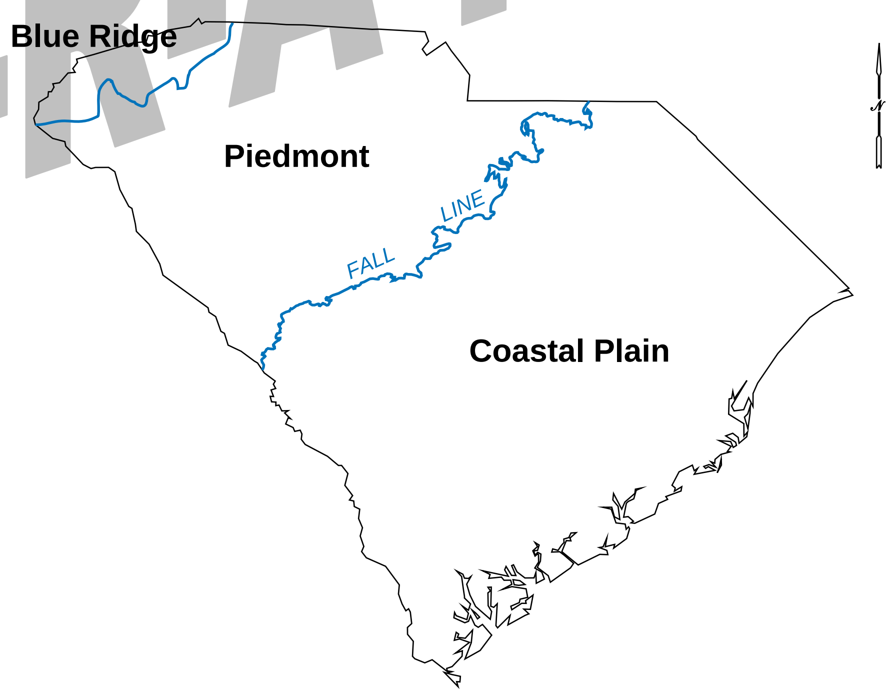


Figure 2. Location of physiographic provinces and the Fall Line in South Carolina.

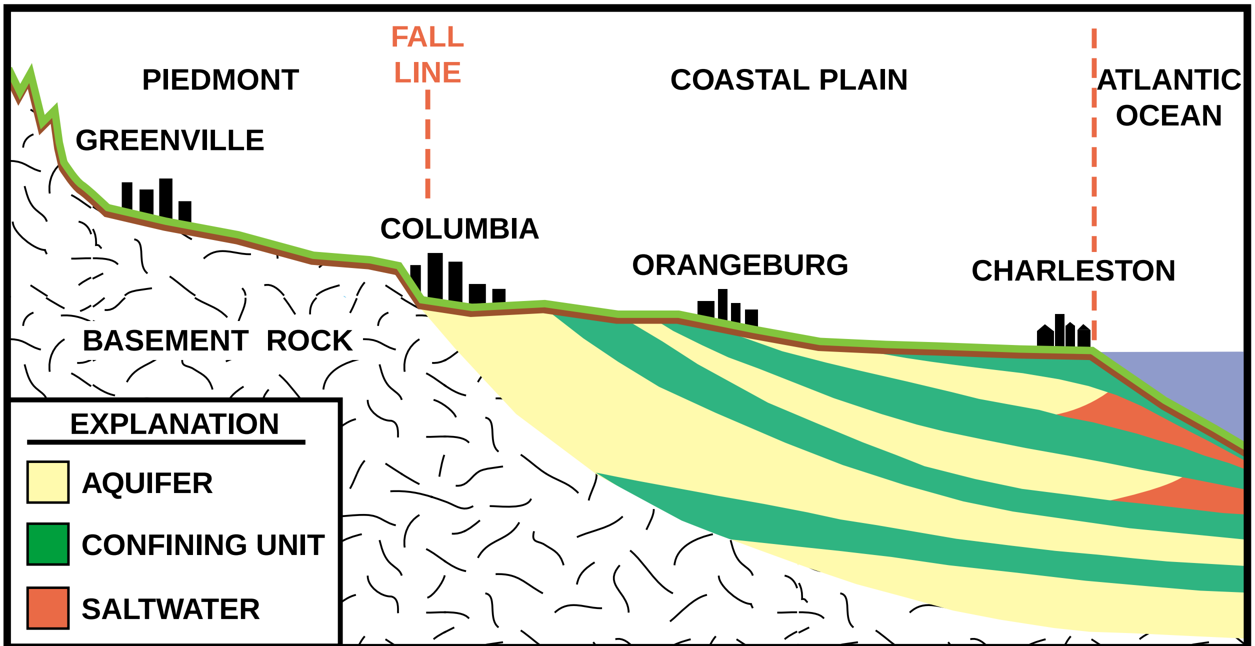


Figure 3. Simplified hydrogeologic cross-section through South Carolina.

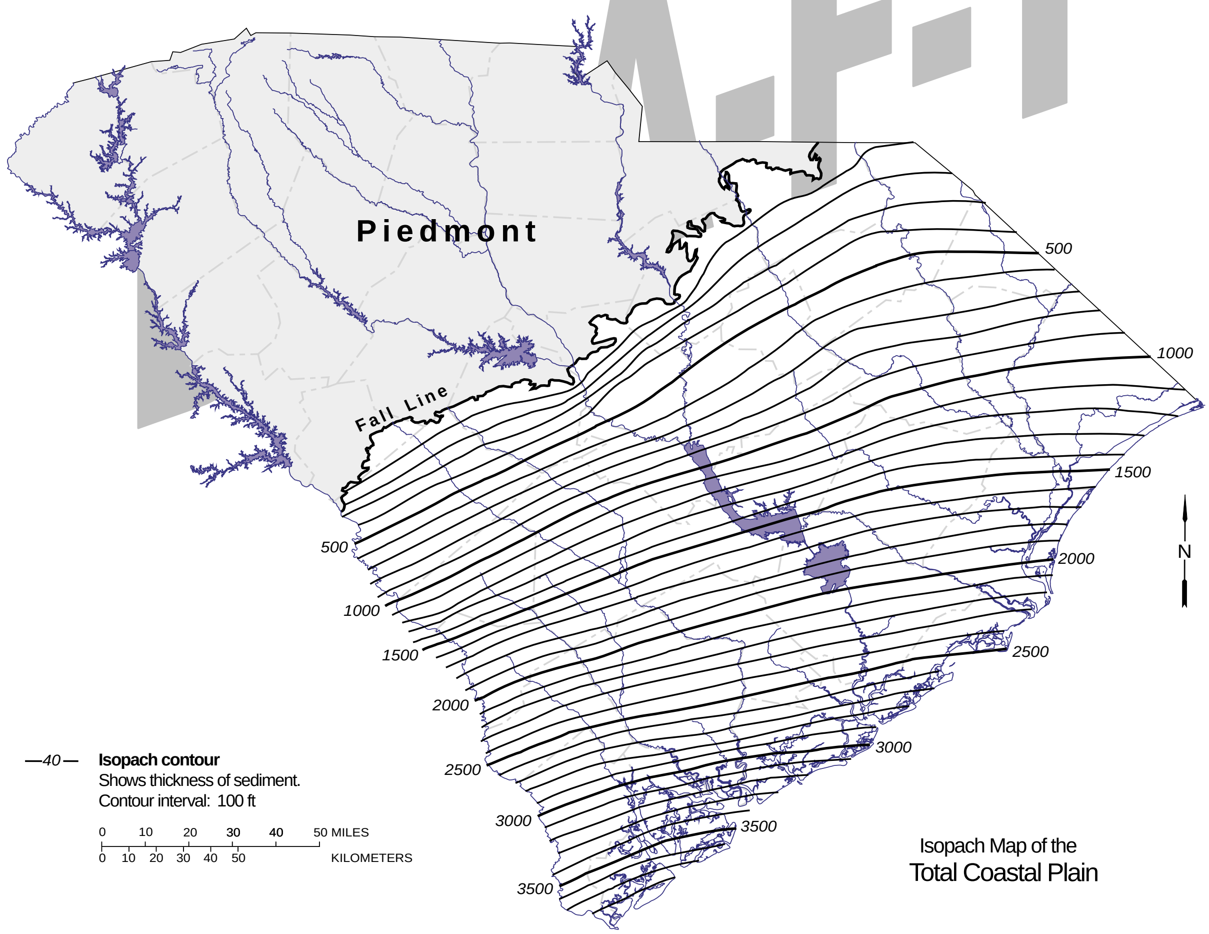


Figure 4. Thickness of Coastal Plain sediments in South Carolina, in feet.

In the Piedmont region, which lacks the porous sediments that form aquifers in the Coastal Plain, ground water is stored in fractures in the bedrock and in a soil-like layer of weathered rock called saprolite that rests upon the bedrock. The continuity and permeability of bedrock fractures and the thickness of saprolite control the occurrence of ground water, which is replenished primarily by precipitation seeping into the saprolite and bedrock fractures. The storage capacity of fractures and saprolite is very small compared to that of the Coastal Plain aquifers.

Because watersheds are defined by surface drainage patterns, the movement of surface water, and, to a large extent, ground water in shallow water-table aquifers, is restricted to whatever basin that water is in. Ground water in deeper, confined aquifers, however, is not confined to any particular basin.

Surface water and ground water are directly connected hydraulically, but their interaction is often overlooked in water resource management considerations. During dry periods, streamflows and lake levels are maintained by discharged ground water (baseflow); at other times, aquifers are recharged when water seeps from lakes and streams into the ground. Because many natural processes and human actions affect this interaction, it is important for water resource managers to consider ground water and surface water as a single resource.

SOUTH CAROLINA'S WATER BUDGET

When water enters a watershed, it becomes part of the total water budget for that watershed, whether it flows on the surface or below it. The water budget equation

Inflow – Outflow = Change in Storage

includes all the water in the watershed.

In a typical year, about 56 inches of water (averaged over the State) comes into South Carolina from all sources. Precipitation is the source of about 48 inches, or 85 percent of the total, and streamflow from North Carolina accounts for the remaining 8 inches. Loss of water from the State occurs primarily through evapotranspiration (the conversion of liquid into vapor by the processes of evaporation and transpiration) and discharge from streams into the ocean. In an average year, 34 inches of water are evapotranspired, 21 inches are discharged into the ocean from streams, and less than 1 inch is discharged into the ocean from aquifers (Figure 5).

Precipitation is distributed unevenly over the State. The mountainous northwestern part of the State receives the most precipitation, the central part receives the least, and coastal areas tend to receive slightly more than inland areas (Figure 6).

Average annual evapotranspiration is also distributed unevenly over the State, being greatest along the coast and in the warmer southern part of the State, and lowest in the cooler Piedmont region (Figure 7).

The annual difference between precipitation and evapotranspiration is greatest in the northwestern part of the State and least in the southern part (Figure 8). When precipitation exceeds evapotranspiration, water is added to the surface- and ground-water systems, increasing streamflow and aquifer storage.

VARIATIONS IN WATER AVAILABILITY

The availability of water—especially surface water—is strongly influenced by seasonal variations in precipitation and evapotranspiration. Precipitation is generally high during the winter and spring months and low during the fall months, while evapotranspiration is generally high during the warmer summer and fall months and low during the winter and spring months (Figure 9). As a result, streamflows and lake levels tend to be higher in the winter months and lower in the summer and fall months (Figure 10).

Ground-water supplies are also subject to seasonal variations and declines due to prolonged droughts, but usually to a smaller extent than are surface-water supplies. Declines in ground-water levels during the drier summer and fall months, the result of both increased pumping and reduced recharge, are usually made up for by increased aquifer recharge and reduced pumping during the wetter winter and spring months (Figure 11). Multi-year droughts lower aquifer water levels by limiting the recharge that normally occurs during the wet winter and spring months (Figure 12).

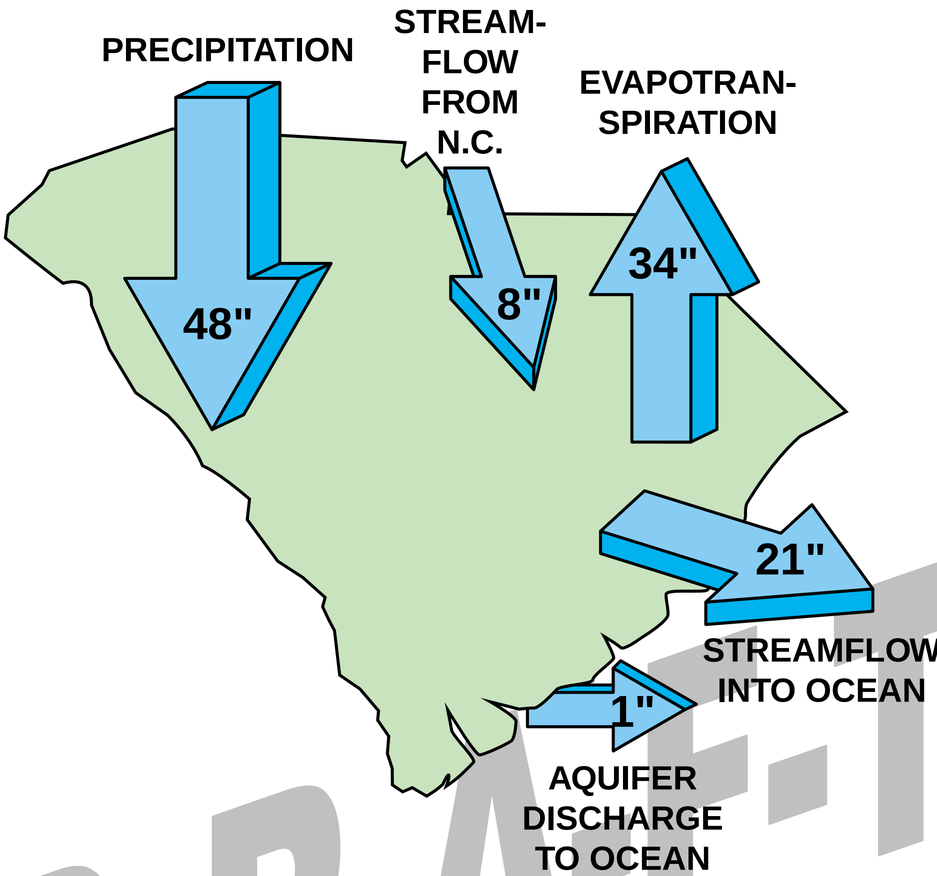


Figure 5. South Carolina's water budget.

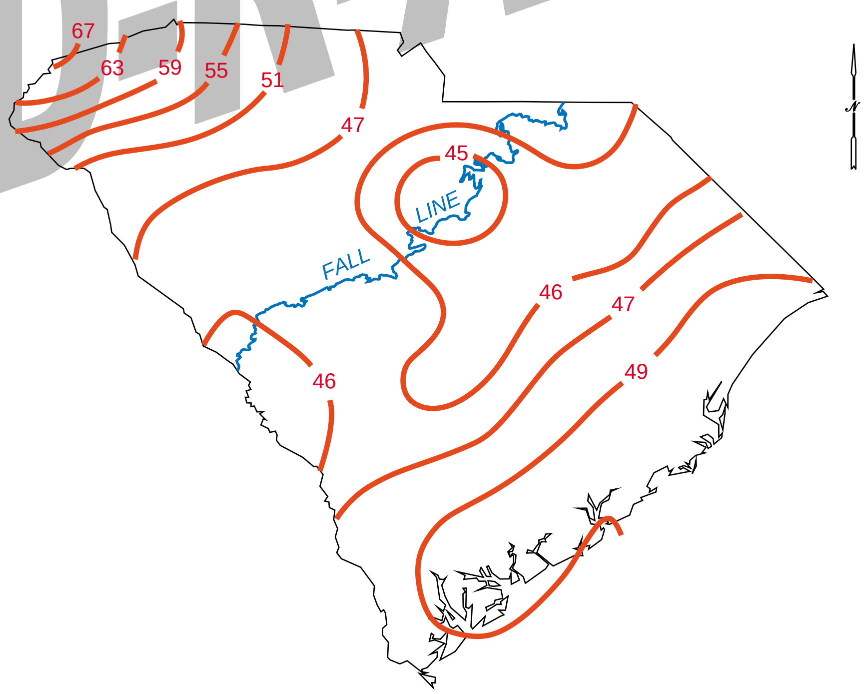


Figure 6. Average annual precipitation, in inches, for the period 1948-1990.

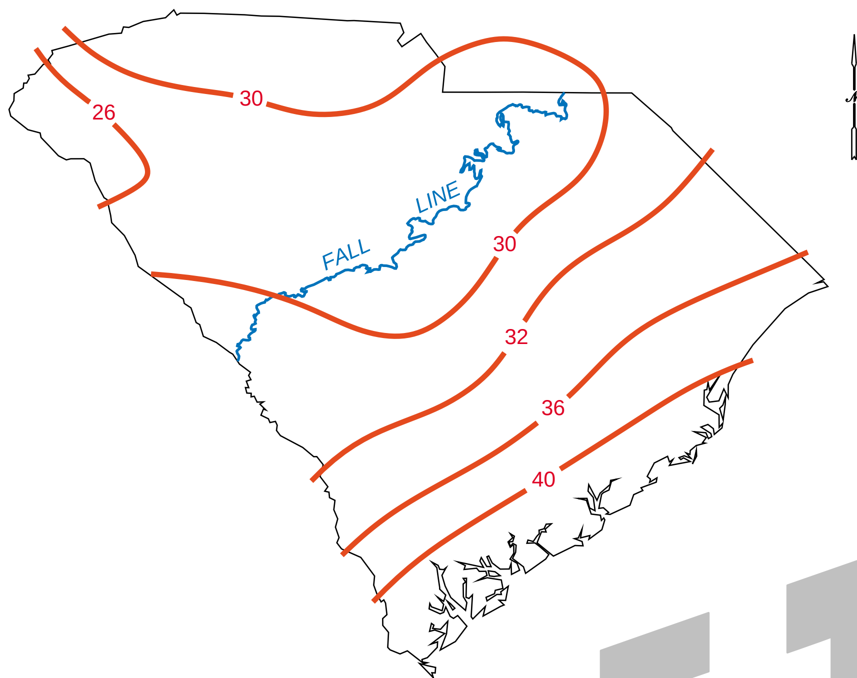


Figure 7. Average annual evapotranspiration, in inches, for the period 1948-1990.

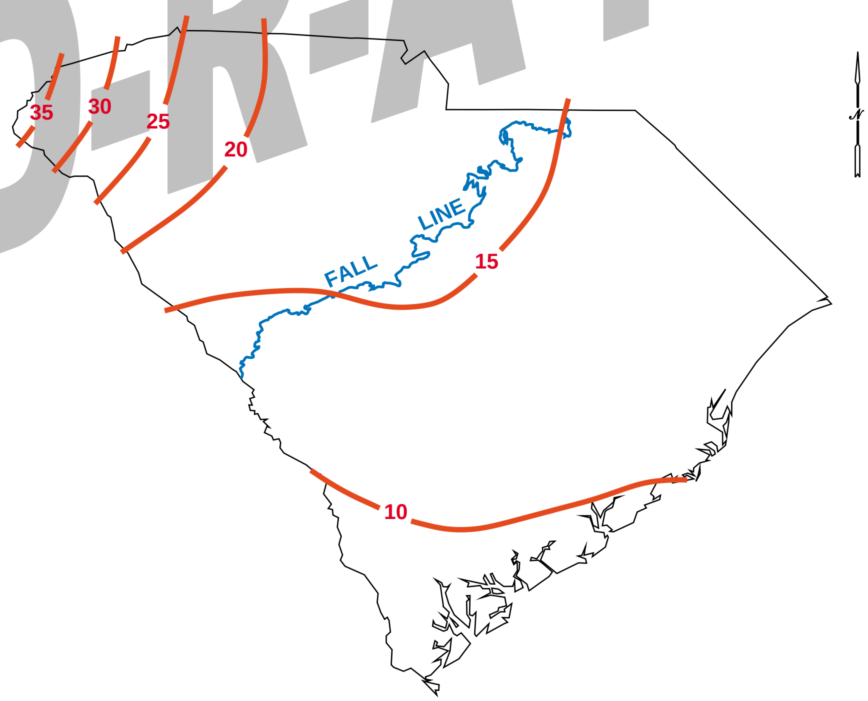


Figure 8. Average annual precipitation less evapotranspiration, in inches, for the period 1948-1990.

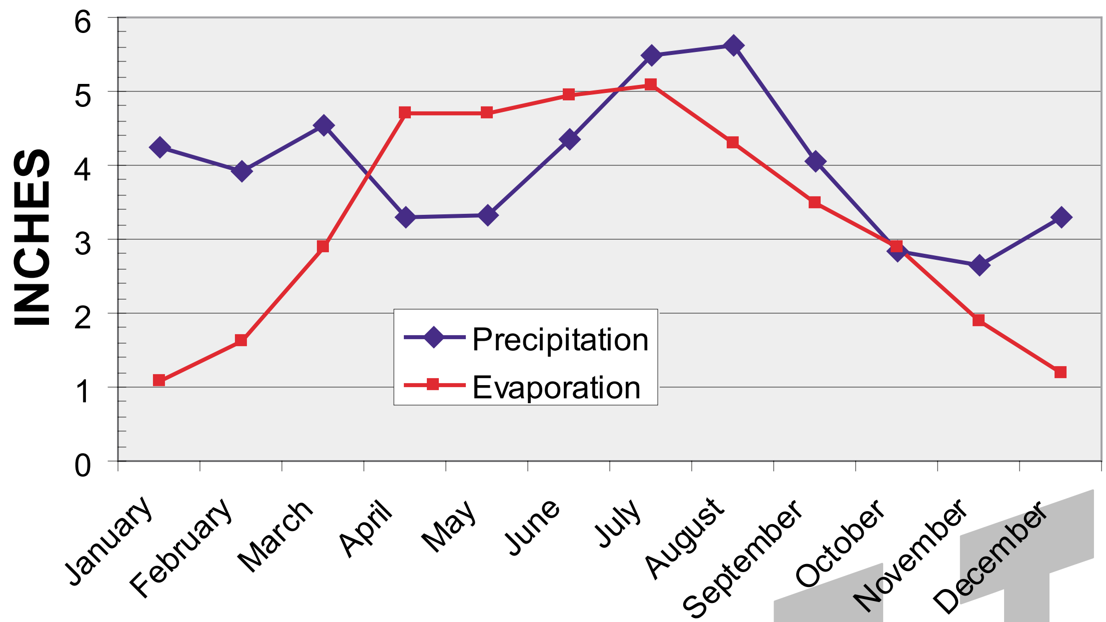


Figure 9. Average annual statewide precipitation and evapotranspiration, by month.

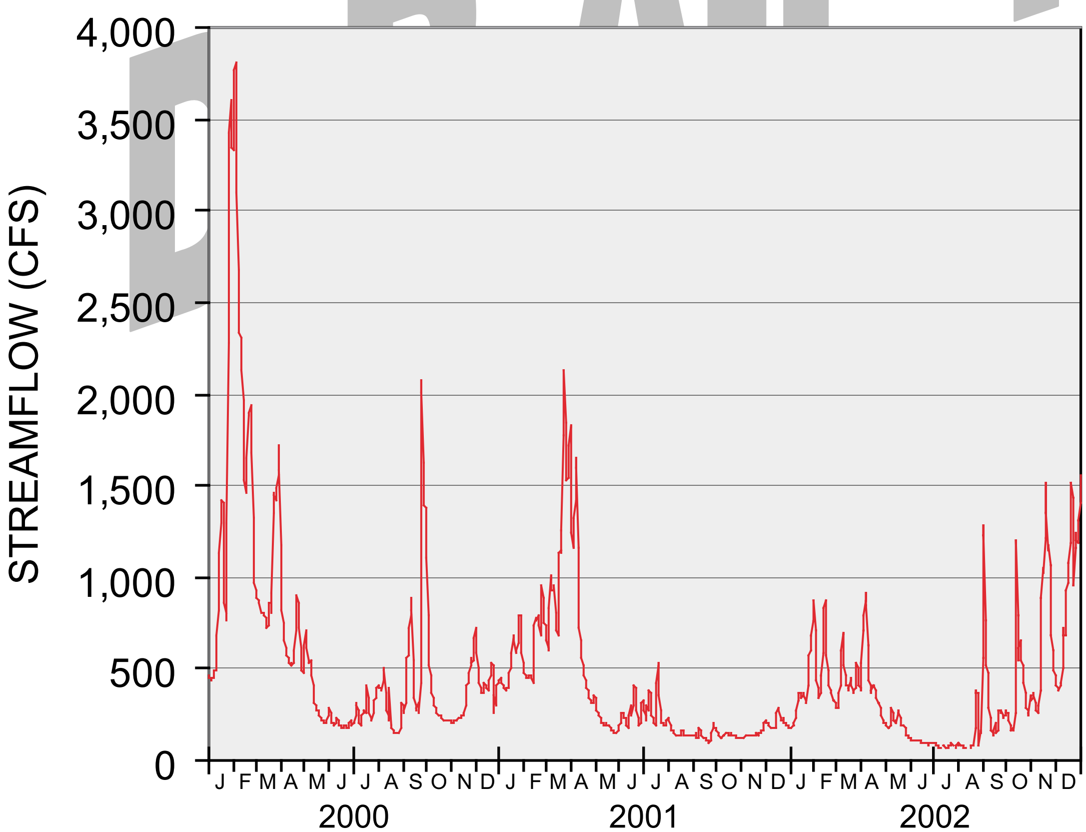


Figure 10. Streamflow in the Lynches River, showing seasonal variations in flow.

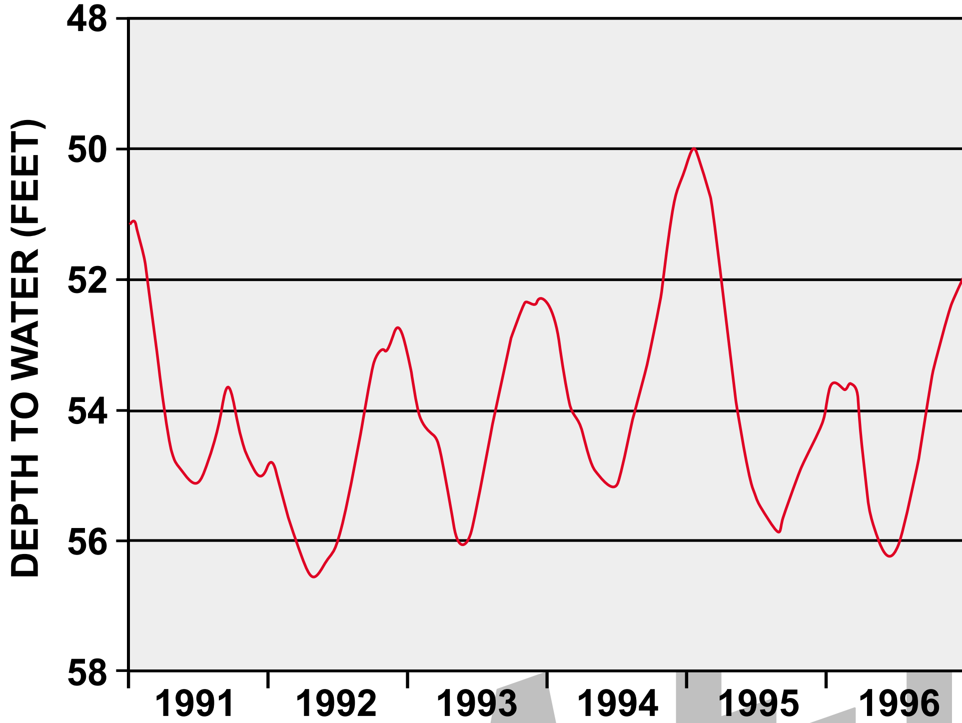


Figure 11. Hydrograph showing typical seasonal variations in ground-water levels.

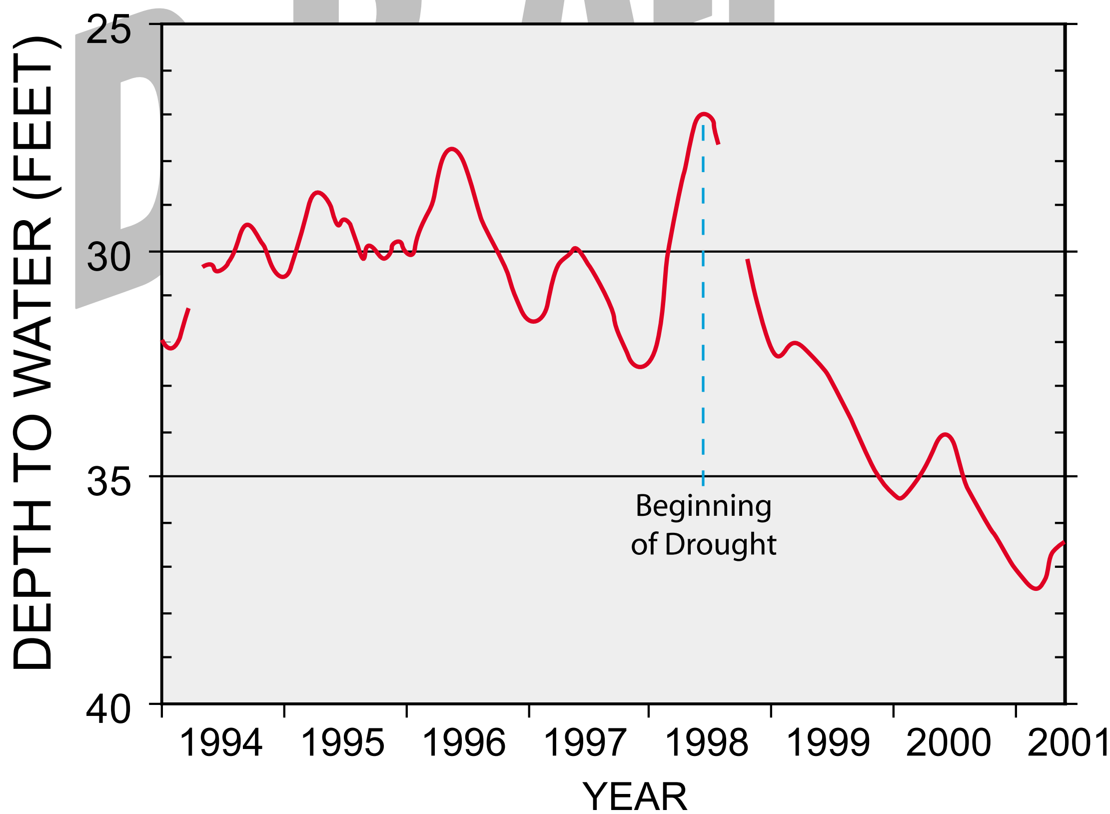


Figure 12. Hydrograph showing effect of prolonged drought on ground-water levels in a Greenville County well.

In addition to seasonal variations in the water supply, long-term variations in the climate can, over time, affect the water supply. Climate changes can affect precipitation, temperature, and evapotranspiration, gradually changing what are thought to be "normal" values. Because the "normal" amount of precipitation is essentially the average annual precipitation for the last 30 years, this "normal" value will change as the climate changes. Figure 13 illustrates how the "normal" rainfall amounts in South Carolina have changed during the 20th Century. Over the past 50 years, there has been a trend toward increasing precipitation; a "normal" amount of rain in the 1990's, for example, would be a greater-than-normal amount of rain in the 1950's.

One of the biggest challenges in water resources management is satisfying the demands of all users at all times by getting the water to where it is needed when it is needed. On average, there is more than enough water in South Carolina to meet the needs of all users, but water shortages can occur because of the highly variable nature of the surface water supply. Seasonal variations in precipitation can produce extreme variations in streamflow rates; tropical storms or long, steady rainfall events can flood rivers that, during drier months, are reduced to much lower-than-normal flows (see Table 1). This wide range of surface water availability is a major problem for resource managers trying to allocate and sustain surface water for all users. Compounding this problem is the fact that demand for water is usually greatest during those times when the supply is lowest.

Table 1. Lowest and highest daily mean flows, in cubic feet per second, during a given year for several streams in South Carolina (data from United States Geological Survey)

Station Name and Location	Lowest Daily Mean Flow (Date)	Highest Daily Mean Flow (Date)	Annual Mean Flow (Year)
Waccamaw River near Longs	58 (Nov. 18, 1999)	28,100 (Sep. 23, 1999)	3,556 (1999)
Congaree River at Columbia	1,360 (Sep. 16, 1998)	90,600 (Feb. 5, 1998)	11,680 (1998)
Stevens Creek near Modoc	7.1 (Sep. 1, 1998)	16,300 (Mar. 9, 1998)	544 (1998)
Coosawhatchie River near Grays	0.06 (Jul. 10, 1998)	7,030 (Feb. 6, 1998)	718 (1998)

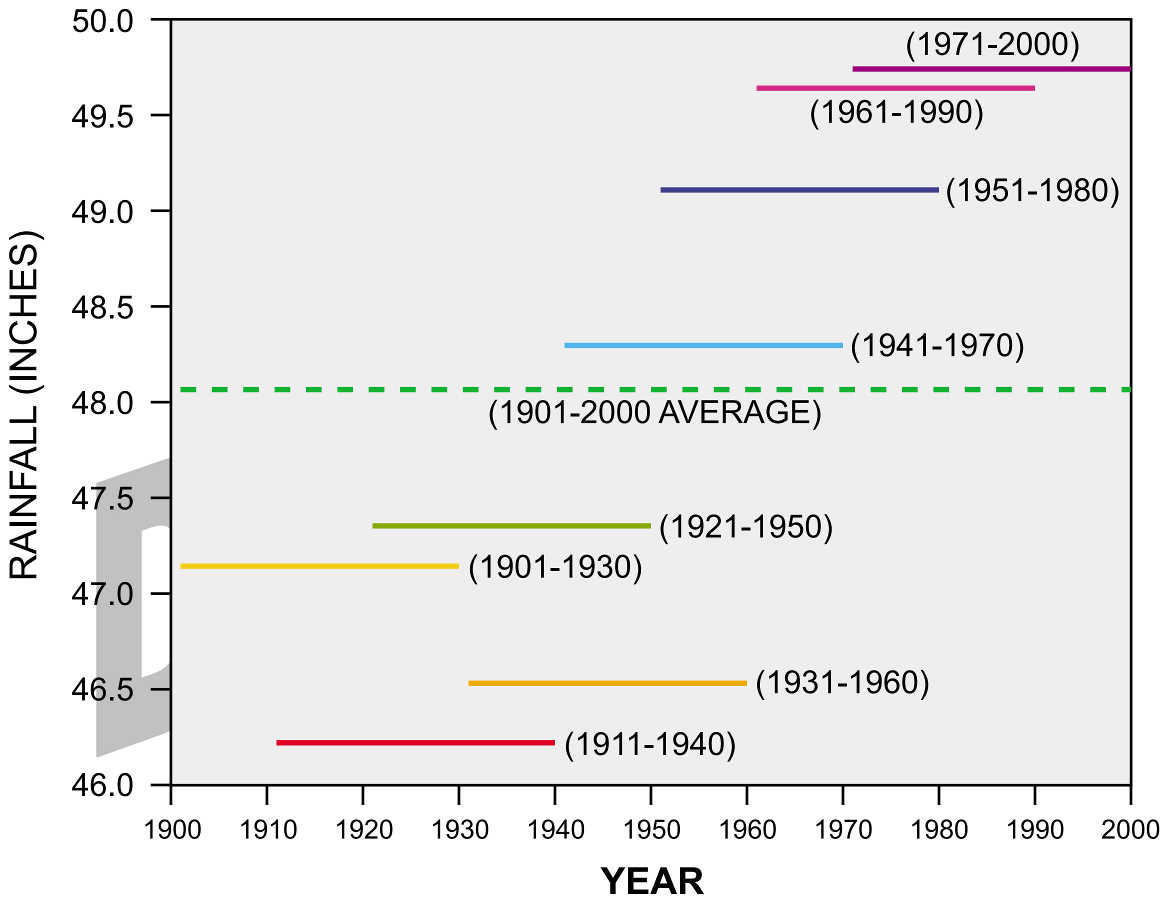


Figure 13. "Normal" precipitation values for South Carolina during the 20th Century.

WATER USE

Two of the most important elements of water resources management are knowing how much water is available, and knowing how much water is being used. Knowing how much water is being used requires accurate and comprehensive water use reporting.

In order to effectively manage the State's water resources, and in particular to minimize the impact of droughts, comprehensive and accurate monitoring of water use is needed. Prior to the early 1980's, water use reporting in South Carolina was not required; reports were supplied voluntarily to State and Federal agencies. Water use reporting became more regular as a result of the South Carolina Water Use Reporting Act of 1982, which required reporting to the State any withdrawals of 100,000 gallons per day or more. Present regulations call for anyone withdrawing in excess of three million gallons in any month to register and report that use annually to the South Carolina Department of Health and Environmental Control (DHEC). Accurate estimates of ground and surface water use are still difficult to obtain. Better regulations and enforcement are needed. Irrigation-use estimates are particularly poor due to inadequate reporting procedures.

INSTREAM USE

All of the uses for surface water and ground water in South Carolina can be classified as either instream use or offstream use. Instream uses are those that take place without diverting or withdrawing water from a stream. Instream uses are nonconsumptive, in that no water is lost from the stream as a result of that use. Instream water uses include maintenance of fish and wildlife habitat, recreation, navigation, wastewater assimilation, and hydroelectric power generation. Hydroelectric power generation has by far the greatest demand for water of all uses, both instream and offstream.

OFFSTREAM USE

Offstream uses are those that involve withdrawing or diverting the water from a stream, lake, or aquifer. The offstream use categories presented here—including thermoelectric power generation, industrial, public supply, crop irrigation, golf course irrigation, and self-supplied domestic—are those used by DHEC in its water use reporting programs. Because offstream uses involve removing water from its source (stream, lake, or aquifer), these uses are usually consumptive, meaning that some of the water withdrawn is not returned to its source.

Thermoelectric power generating facilities—both nuclear and fossil fuel—use large quantities of water for cooling purposes. At these facilities, tens of millions of gallons per day are lost to evaporation and become unavailable to downstream users. These losses, although seemingly large, represent only 1 to 2 percent of the total volume of water used.

Industrial water use includes water used for washing, cooling, manufacturing, and processing materials, primarily chemicals and allied products. This use category represents self-supplied industries, and does not include water used for industrial purposes that was purchased from a public supply system.

Public supply includes any public or private utility that distributes water for sale to the public primarily for domestic, commercial, or industrial use. The majority of the State's large public supply systems depend on surface water, but there are some systems in the Coastal Plain—the City of Sumter being the largest—that rely entirely on ground water.

Crop irrigation represents self-supplied water used for agricultural and horticultural irrigation, except for golf course irrigation. Irrigation generally occurs during a 150-day period from late March through August. During this growing season, irrigation use can have a significant impact on the overall water supply. Crop irrigation is highly consumptive; much of the water withdrawn is often lost to evapotranspiration.

Golf course irrigation represents all self-supplied water artificially applied to golf courses. This water use is greatest in the coastal counties, which have the majority of the golf courses. Like crop irrigation, golf course irrigation is highly consumptive.

Self-supplied domestic use represents the water used by the population not served by public supply systems. Practically all of these withdrawals are from ground-water sources. This use was calculated by applying a water use rate of 75 gallons per day per person not served by a public supply system.

Other offstream use categories include **mining** (water used for the extraction, dewatering, milling, and other preparations that are part of mining activities), **aquaculture** (water used for the production of aquatic organisms in captivity), **commercial** (water used for hotels, restaurants, office buildings, civilian and military institutions, and other commercial facilities), and **livestock** (water used for animals, feed lots, dairies, poultry, and animal specialties). These uses make up a very small percentage of the total offstream water use, and are therefore not included in the water use data presented in the following section.

The **interbasin transfer** of water is an offstream use not included in DHEC's water use categories. Regardless of the eventual use for the water at its destination, interbasin tranfer is a 100-percent consumptive offstream use for the source basin.

WATER USE IN THE YEAR 2000

Water use data for the year 2000 is presented to illustrate the relative magnitudes of the water uses in South Carolina. These numbers come from the forthcoming revised *South Carolina State Water Assessment*, which contains a detailed description of how these estimates were made.

Hydroelectric-power water use (instream) was estimated at 36,175 MGD (million gallons per day) for the year 2000, which is less than 75 percent of the 50-year average for this use. This very low total—the third smallest annual total since 1950—is the result of the drought that began in 1998; reduced streamflows and lake levels limited the amount of water available to generate electricity.

Offstream water withdrawals in South Carolina during the year 2000 totalled 7,362 MGD, of which 5,840 MGD was used for thermoelectric power generation. The combined total of all other offstream uses for the year 2000 was 1,522 MGD, of which industry used 37 percent, public supply 36 percent, crop irrigation 17 percent, golf course irrigation 6 percent, and self-supplied domestic 4 percent. Streams and lakes provided nearly all of the supply for hydroelectric and thermoelectric power generation, and 71 percent of the supply for all other uses. Wells and springs provided the remaining 29 percent. Table 2 lists the water use data by county in South Carolina for the year 2000, and Table 3 presents a summary of water use for each basin during that same year.

TRENDS

Water use in South Carolina is linked to many social, economic, technological, and regulatory factors. The demand for water is closely tied to the State's population; as the population grows, so too will the demand for water. Further industrial development and the ever-increasing demand for electricity will also increase the need for available water. The combined water demand for industry, public supply, crop and golf course irrigation, and domestic use is expected to increase by nearly 50 percent between the years 2000 and 2045 (Castro and Foster, 2000) (Figure 14).

Table 2. Estimated water use (million gallons per day) in South Carolina, by county, for the year 2000

COUNTY	HYDRO-ELECTRIC	THERMO-ELECTRIC	PUBLIC SUPPLY	INDUSTRY	IRRI-GATION	GOLF COURSE	DOMESTIC	SUB-TOTAL
Abbeville	3,273		3.41	1.67	1.08	0.30	0.73	7
Aiken		161	19.32	81.71	5.85	3.00	0.80	111
Allendale			1.20	2.95	14.94	0.10	0.27	19
Anderson	2,232	75	20.41	2.09	1.61	2.30	0.36	27
Bamberg			0.79	0.08	12.94	0.40	0.41	15
Barnwell			3.20	0.91	16.46	0.50	0.63	22
Beaufort			23.50	0.89	5.06	15.20	0.52	45
Berkeley	5,222	585	12.77	11.77	1.83	1.50	3.60	31
Calhoun			0.91	90.20	21.20	0.30	0.61	113
Charleston			53.38	39.29	8.04	6.00	2.56	109
Cherokee	1,022		12.03	2.30	1.75	0.60	0.37	17
Chester	3,105		3.52	0.79	0.31	0.60	1.45	7
Chesterfield			5.89	1.53	1.50	1.00	0.84	11
Clarendon			1.83	0.10	5.72	1.50	1.07	10
Colleton		3	2.35	0.13	3.69	0.40	1.30	8
Darlington		824	6.27	18.10	3.53	1.50	0.42	30
Dillon			4.87	2.21	1.80	0.20	0.40	9
Dorchester			7.49	3.33	0.60	1.50	1.92	15
Edgefield	2,660		3.60	0.10	7.33	0.50	0.11	12
Fairfield	4,825	803	2.29	0.10	2.46	0.20	0.50	6
Florence			14.82	37.84	5.29	1.30	2.81	62
Georgetown		12	7.43	32.03	4.79	4.20	0.43	49
Greenville	571		56.57	0.76	5.11	6.20	2.87	72
Greenwood	477		13.18	0.40	0.09	1.90	1.33	17
Hampton			1.80	1.76	5.68	0.70	0.47	10
Horry		104	30.24	3.10	3.14	19.40	1.44	57
Jasper			1.26	0.15	2.16	0.40	0.18	4
Kershaw	1,652		7.28	13.30	0.45	0.80	0.40	22
Lancaster	1,165		11.84	13.75	0.95	1.30	0.68	29
Laurens	295		5.96	0.13	3.17	0.80	0.90	11
Lee			1.58	1.93	0.77	0.20	1.25	6
Lexington	288	146	18.24	44.10	18.30	2.30	8.46	91
McCormick	3,266		1.71	0.01	1.34	0.90	0.08	4
Marion			4.71	2.43	1.90	0.30	0.59	10
Marlboro			3.10	9.66	2.92	0.40	0.81	17
Newberry			5.16	0.38	0.87	0.60	1.05	8
Oconee	32	2,596	10.12	2.33	1.44	1.50	0.53	16
Orangeburg			9.60	8.80	47.60	1.50	1.29	69
Pickens	492		13.18	1.58	0.71	1.60	1.86	19
Richland	1,222	438	57.61	29.62	1.77	4.30	1.65	95
Saluda			0.63	0.15	6.07	0.30	0.95	8
Spartanburg	46		39.80	3.82	3.13	3.30	3.53	54
Sumter			16.13	2.59	13.18	1.30	2.53	36
Union	3,047		4.46	3.65	0.76	0.40	0.25	10
Williamsburg			1.64	4.77	2.31	0.30	1.93	11
York	1,283	93	14.68	86.50	1.00	3.20	6.41	112
South Carolina	36,175	5,840	542	566	253	97	64	1,522

***Sub-totals do not include hydroelectric or thermoelectric uses.**

Table 3. Estimated water use (million gallons per day) in South Carolina, by basin, for the year 2000

	BASIN	HYDRO-ELECTRIC	THERMO-ELECTRIC	PUBLIC SUPPLY	INDUSTRY	IRRI-GATION	GOLF COURSE	DOMESTIC	SUB-TOTAL
Surface Water	Savannah	11626	2757	53	81	16	7	0	157
	ACE	2926	588	92	53	58	20	0	223
	Santee	21621	1554	251	283	32	21	0	587
	Pee Dee	0	940	41	103	20	23	0	186
	Statewide	36173	5839	437	519	126	71	0	1153
Ground Water	Savannah	0	0	6	9	16	2	5	38
	ACE	0	4	29	15	58	9	15	127
	Santee	0	0	11	7	32	7	30	87
	Pee Dee	0	0	58	20	20	8	13	119
	Statewide	0	4	104	51	126	26	64	371
Total Water	Savannah	11626	2757	59	90	33	9	5	195
	ACE	2926	592	121	68	116	29	15	350
	Santee	21621	1554	262	290	64	28	30	675
	Pee Dee	0	940	99	123	40	31	13	305
	Statewide	36173	5843	541	570	253	97	64	1525

* Sub-totals do not include hydroelectric or thermoelectric uses.

** Irrigation use estimates are based on a 5-month growing season. The source of irrigation water is assumed to be half surface water and half ground water.

*** Some values do not equal those of Table 2 because of rounding errors.

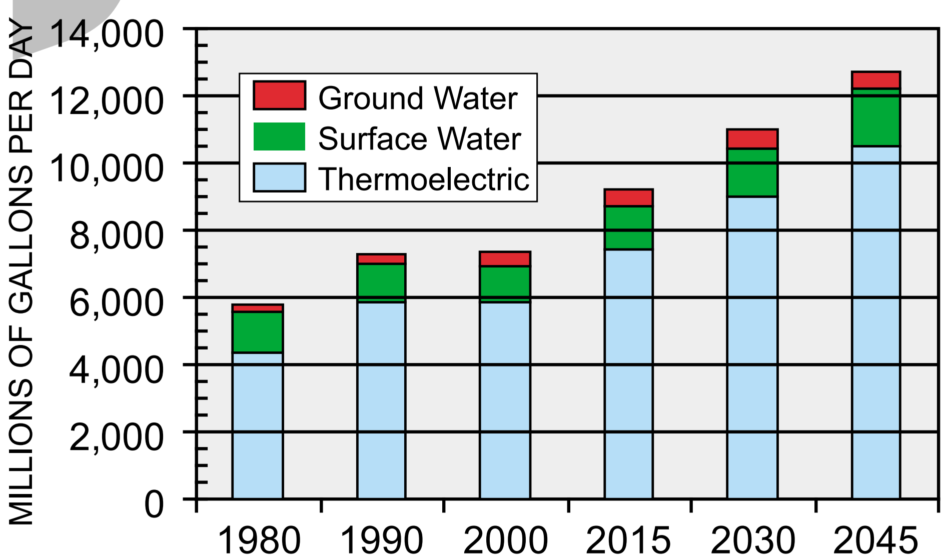


Figure 14. Past water use and projected water demand for South Carolina (Castro and Foster, 2000).

WATER RESOURCES MANAGEMENT

Early in this State's history, rivers were used for transportation, irrigation, and drinking water. Over time, rivers were harnessed to provide mechanical power for mills, and in the 20^{th} Century, water wheels gave way to hydroelectric turbines, as massive dams were built to generate electricity and provide some degree of flood control. By the end of the 20^{th} Century, most of South Carolina's larger rivers were regulated by releases from impoundments, several of which are located in North Carolina. Only in the ACE Basin (see Figure 1) are any major rivers in South Carolina still unregulated and flowing naturally.

The regulation of South Carolina's rivers was by far the most important water resources management decision in the State's history. Dams and reservoirs provided many benefits, such as electricity, flood control, water supply, sustained flows during dry periods, and increased recreational and tourism opportunities. But the dams also created some problems, such as altered flow regimes, interrupted fish passage, destroyed and altered habitats, and changes in water chemistry.

In the later part of the 20^{th} Century, the water demands of an increasing population and growing industrial base, as well as greater environmental awareness, led to an increasing need for effective water resources management. The South Carolina Water Resources Commission was established in 1967 to provide the State with an assessment of its water resources, and to offer management guidelines for sustaining the State's water resources for future generations.

Today, water resources planners and managers are faced with many issues, such as monitoring and protecting water quality and quantity, determining and maintaining minimum flows in rivers, protecting riverine habitats and ecosystems, regulating releases from reservoirs, allocating water during shortages, maintaining navigation, and managing floodplain development. Many of these issues stem from an increasing population making increasing demands on the finite water resources of the State.

In addition to problems caused by competing demands, the withdrawal or diversion of water from a lake, stream, or aquifer may cause undesired effects, such as saltwater intrusion, lowering of water levels in a lake or wetland, diminishing the flow to a stream, reducing the ability of an aquifer to produce water, lowering the water level in nearby wells (well interference), land subsidence, or sinkhole formation. These adverse effects can be mitigated by restricting withdrawal, diverting water from other areas, withdrawing water from a stream rather than from an aquifer or vice versa, or taking water from water storage facilities such as lakes or reservoirs.

The effective management of South Carolina's water resources—finding ways to satisfy the many conflicting demands while still protecting the resource for future generations—is beyond the scope of any one agency or organization, and will require cooperation and shared responsibility among public and private parties.

Effective resource management requires the increased utilization of regulatory science—research directed to provide useful information for regulators facing specific choices. Research institutes and universities should be encouraged to work with State resource agencies and become integrated into the decision-making processes of the State. South Carolina needs integrated, long-term research projects to answer specific regulatory questions.

The management of South Carolina's water resources is a task made difficult by the complexity of the system and the interconnection of its components. Water quantity affects water quality; water quality affects the quantity of available water; lakes affect rivers; ground water affects surface water; surface water affects ground water; and climatic conditions ultimately control all these components. Because of the complex interaction of all the components of the State's water resources system, management strategies must be flexible, responsive to trial, monitoring, and feedback, and should change in response to new scientific information and technical knowledge. This "adaptive management" approach provides a process for continually improving management practices and policies.

Whether dealing with surface water or ground water, there are two major issues facing water resource managers: *water quantity*—making sure there is enough water at the right place at the right time; and *water quality*—making sure the available water is suitable for use.

SURFACE WATER QUANTITY

The flow of unregulated streams and rivers is essentially controlled by climatic and geographic conditions, outside the influence of man. Quantity management programs for these rivers are therefore limited primarily to water allocation and conservation mechanisms. Regulated streams and rivers, on the other hand, are strongly controlled by man, and as such offer a much better opportunity to manage the quantity and location of the surface water. The management of the reservoirs that control South Carolina's rivers is the key to the effective management of the State's surface water resources.

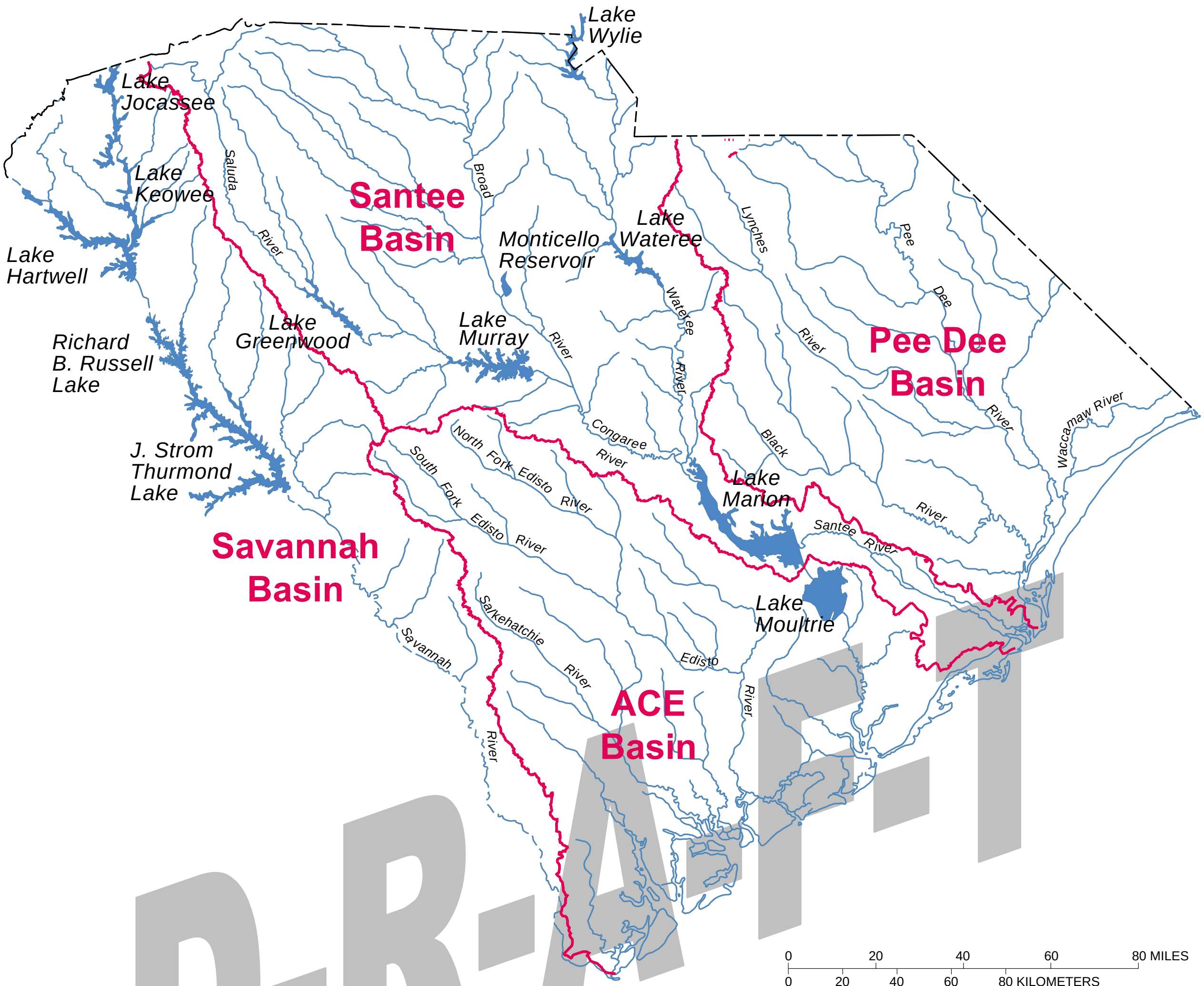
An essential element of any successful water quantity management program is knowing how much water there is, and where it is, at any given time. To that end, a good monitoring network is a requirement for an effective surface water management program.

South Carolina's Rivers

There are more than 11,000 miles of permanently flowing streams and rivers in South Carolina (SCWRC, 1988), having an average flow of about 33 billion gallons per day (SCWRC, 1983). The State's streams and rivers are located within four major drainage basins (Figure 15), and many of these rivers are shared with Georgia or North Carolina. Most of South Carolina's major rivers are highly regulated by releases from instream reservoirs.

The Savannah River, which forms the Georgia-South Carolina border, is the dominant river in the Savannah Basin, and is heavily regulated by releases from Lakes Hartwell, Russell, and Thurmond.

In the Santee Basin, the Saluda River and Broad River enter South Carolina from North Carolina and converge to form the Congaree River near Columbia. The Catawba River, entering South Carolina near Charlotte, becomes the Wateree River before merging with the Congaree to form



Rank	Lake	Drainage basin	Lake owner	Surface area (acres)	Volume (acre-feet)
1	Hartwell	Savannah	Corps of Engineers	56,000	2,549,000
2	Thurmond	Savannah	Corps of Engineers	70,000	2,510,000
3	Murray	Santee	SCE&G	51,000	2,114,000
4	Marion	Santee	Santee-Cooper	110,000	1,400,000
5	Moultrie	ACE	Santee-Cooper	60,000	1,211,000
6	Jocassee	Savannah	Duke Power	7,565	1,185,000
7	Russell	Savannah	Corps of Engineers	26,650	1,026,000
8	Keowee	Savannah	Duke Power	18,372	1,000,000
9	Monticello	Santee	SCE&G	6,800	431,050
10	Wateree	Santee	Duke Power	13,710	310,000
11	Wylie	Santee	Duke Power	12,455	281,900
12	Greenwood	Santee	Duke Power	11,400	270,000

Figure 15. Major rivers and the 12 largest lakes, by volume, in South Carolina.

the Santee River at Lake Marion. All of these rivers are controlled by releases from reservoirs in South Carolina and North Carolina.

Most of the major rivers of the Pee Dee Basin—the Pee Dee, Little Pee Dee, Lynches, and Waccamaw—originate in North Carolina and receive much of their flow from drainage in that state. The Black River is the largest river in this basin that originates within South Carolina. There are no major reservoirs within this basin in South Carolina, but the flow of the Pee Dee River is controlled by reservoir operations in North Carolina.

The ACE Basin is the only major drainage basin located entirely within South Carolina, and most of its major rivers—the Ashley, Edisto, Salkehatchie, Coosawhatchie, and Combahee—are essentially unregulated. Only the Cooper River, which flows from Lake Moultrie to the Charleston Harbor, is significantly regulated.

South Carolina's Lakes

There are more than 1,600 lakes in South Carolina that cover an area of ten acres or more (SCWRC, 1991), impounding more than 15 million acre-feet of water, 95 percent of which is contained within the State's 12 largest reservoirs (Figure 15), and releases from these man-made lakes control the flow of many of the State's rivers.

All of these major reservoirs were constructed for the primary purpose of hydroelectric power generation, and that function is still the guiding force behind reservoir operations. The lakes also provide some flood control by reducing the severity of peak flood flows, and they help to supplement low flows during extended dry periods. Reservoirs also serve as reliable sources of water for many cities and water companies across the State.

In the years since they were constructed, South Carolina's lakes have become nationally known for their boating, fishing, and recreational opportunities. Recreational use of lakes has become an important economic asset, and this use needs to be given important consideration in any lake management program.

In the Savannah Basin, Lakes Thurmond, Russell, and Hartwell dominate the upper Savannah River and effectively control the flow of the lower Savannah River. These reservoirs, operated by the U. S. Army Corps of Engineers, are located on the Georgia-South Carolina border, and are shared by the two states. Lakes Jocassee and Keowee, both located entirely within South Carolina, flow into Lake Hartwell via the Seneca River.

The Santee Basin contains six of the 12 largest lakes in South Carolina: Lakes Murray and Greenwood on the Saluda River; Lakes Wylie and Wateree on the Catawba/Wateree River; Monticello Reservoir off the Broad River; and Lake Marion on the Santee River. (Although Lake Moultrie gets its water from the Santee River via Lake Marion, the reservoir itself is located in the ACE Basin.) In addition to these South Carolina lakes, there are several more reservoirs in North Carolina that regulate flows of the Broad River and Catawba River before they enter South Carolina.

Although there are no major reservoirs on the rivers of the Pee Dee Basin in South Carolina, this basin is influenced by reservoirs located in North Carolina. The Pee Dee River, for example, is controlled by six reservoirs in North Carolina.

Only in the ACE Basin are most of the rivers undammed and in a relatively "natural" condition. But even this basin contains one major reservoir: Lake Moultrie, which gets its water from Lake Marion via a cross-basin canal. Lake Moultrie discharges some of its water into the Cooper River, enhancing natural flows into the Charleston Harbor, while the rest of its discharge is returned to the Santee River.

Lakes and Rivers are Interconnected

Lakes and rivers are inherently connected and interdependent. What happens in a river affects every lake downstream, and what happens in a lake affects the river downstream. Management of the State's surface water system requires a coordinated management of its lakes and rivers in order to balance the needs of lake users with the needs of river users. Lakes cannot be operated without regard for the needs of downstream users, with respect to both water quantity and quality. Likewise, the needs of river users cannot necessarily outweigh the needs of lake users.

The construction of an instream reservoir has a profound impact on the river in which it is constructed. Some of the impacts are beneficial, such as sustaining streamflows during extended dry periods, whereas other impacts are detrimental, such as decreasing the downstream river's dissolved oxygen concentrations, hindering navigation, altering habitats, and preventing fish passage past the dam. Perhaps the most significant impact a reservoir has on its river is the change in the downstream flow regime.

Management Guidelines for Rivers

South Carolina's rivers are one of its most important resources, and their wise use and management is clearly in the State's interest. The complexity of South Carolina's river systems, their dependence on unpredictable and uncontrollable weather patterns, and the diverse multitude of users and their demands all contribute to the complexity of managing South Carolina's streams and rivers.

Some of the major issues facing resource managers are developing appropriate release schedules for reservoirs, establishing desired and minimum allowable flows, monitoring both water quantity and quality, protecting habitats and ecosystems, maintaining and restoring water quality, controlling point and nonpoint sources of pollution, allocating water during times of shortage, managing floodplain development, dredging channels, controlling invasive exotic species, and maintaining navigation.

Many of these issues are being addressed, to some extent, by federal, state, and local government agencies, as well as by private organizations, particularly the environmental issues. For example, the DNR's Scenic Rivers Program works to conserve unique ecological, cultural, recreational, and scenic resource values in South Carolina's rivers. Through a cooperative, voluntary management process involving landowners, community interests, and the DNR working together for common river management goals, more than 250 miles along segments of eight rivers are being managed and protected as State Scenic Rivers.

Minimum Required Flows

Minimum required flows for streams need to be established to protect public health and safety, maintain fish and wildlife, and provide recreation while promoting aesthetic and ecological values. The minimum required flow for a stream is the greatest of the minimum flows required for:

1. Protection of water quality;
2. Protection of fish and wildlife habitats;
3. Maintenance of navigability;
4. Estuary maintenance and prevention of saltwater intrusion.

Protection of water quality—Streamflows must be maintained to protect human health and safety and to prevent irreversible damage to the ecosystem.

The *assimilative capacity* of a stream refers to the amount of wastewater and other pollutants a stream can receive without causing harmful effects to aquatic life or humans who consume the water. The assimilative capacity is directly related to how much water is in the stream; higher flows can handle larger amounts of pollutants before becoming adversely affected.

DHEC, the State agency responsible for overseeing and regulating wastewater discharge, uses the "7Q10" flow to determine the wasteload capacity of a stream. The 7Q10 flow is a statistically determined value and is defined as the lowest mean streamflow over 7 consecutive days that can be expected to occur once in a 10-year period. In any year, there is a 10-percent probability that the average flow for 7 consecutive days will be equal to or less than the 7Q10. In general, DHEC allows treated waste discharges into a stream only to the extent that the 7Q10 flow of that stream can adequately handle that permitted discharge.

7Q10 values are not fixed numbers, and should not be thought of as fixed values; they can vary over time as water availability changes during wet and dry periods. To maintain water quality during prolonged dry periods, when flows frequently drop below established 7Q10 values, regulatory programs should have the flexibility and authority to reduce permitted waste discharges. If 7Q10 values are used for comparison of different drainage areas, they should both be calculated from the same period of record.

Protection of fish and wildlife habitats— Reduced flows decrease the amount of habitat available to aquatic biota and can restrict the movement of resident and migratory fish species. Reduced flows also intensify pollution, inflate water temperature, and exacerbate dissolved oxygen problems, all of which can damage riverine habitats and ecosystems.

It is the responsibility of the DNR to determine the minimum flow required to protect the State's aquatic resources. The current policy for determining instream flow requirements for fishery resources can be found in *South Carolina Instream Flow Studies: A Status Report* (Bulak and Jöbsis, 1989). Work is currently underway to determine if it is more appropriate to prescribe minimum flows based on a percentage of mean monthly flows, rather than mean annual flow, as employed by Bulak and Jöbsis (1989). Basing minimum flows on mean monthly flows has the advantage of a closer adherence to a stream's natural flow pattern. This methodology would require a technique for estimating the natural flow pattern of regulated rivers, and would also require an evaluation of the change in habitat at various percentages of mean monthly flow.

Maintenance of navigability—Minimum flow requirements for navigation are based on either one-way or two-way navigation (SCWRC, 1988). The minimum flow for one-way passage by boat for a given stream segment will provide a minimum depth of 1 foot across a channel 10 feet wide or across 10 percent of the total stream width, whichever is greater. The minimum flow for two-way passage by boat would provide a minimum depth of 2 feet across a channel 20 feet wide, or across 20 percent of the total stream width, whichever is greater.

Prevention of saltwater intrusion—Estuaries are essential habitats for numerous marine resources, and adequate freshwater flow into estuaries is necessary to maintain the ecological functions that support recruitment of important recreational finfish and shellfish populations. Freshwater flow in coastal rivers must also be maintained to keep saltwater away from the intake structures of water supplies. Measured data of saltwater advances into rivers during different flows should be used to build and verify simulation models to enhance the management of flow regimes in rivers in order to control the saltwater wedge and maintain the ecological functions of estuaries. Minimum flows required to prevent undesirable saltwater intrusion should be determined by the DNR.

Allocation of River Water

South Carolina's streams and rivers usually have more than enough water to satisfy the demands of all water users. However, during dry summers or prolonged droughts, streamflows can become unusually low, and demands for water can exceed the available supply. To maximize water availability at all times and to protect human and economic needs, surface water use must be regulated. An allocation mechanism must be established to control the distribution of water so that all users have a reliable water supply. Variations in surface water availability and the location of withdrawals must play major roles in the allocation of water.

At any given withdrawal site, there is a quantifiable amount of *available water* that can be removed from a stream without adversely impacting downstream users. This available water is the difference between how much water is in a river at the withdrawal point and how much water must be left instream for downstream use. Any withdrawals, discharges, and drainage recruitments occurring upstream from the withdrawal point are incorporated into the measured flow at the withdrawal point. The amount of water needed for downstream use is the sum of all downstream permitted withdrawals, discharges, recruitments, and required instream flows. The amount of available water will vary with changes in streamflow or offstream use.

There will be times when the available water is less than the desired withdrawal amount. How often this is likely to occur can be determined by examining the stream's historical measured flow data. A duration curve—a statistical analysis of how often various flows occur—can provide an estimate of how often the desired withdrawal amount will be available, and the stream's measured flow history can provide an estimate of the longest continuous period during which the streamflow will be inadequate to provide to desired withdrawal amount. The summation of flow deficit during this period represents how much additional water would be needed from other sources to supplement the natural flow in order to meet the user's demands during this dry period. This supplemental water can come from storage facilities, ground water, or other water suppliers.

During extended dry periods, reduced water availability may necessitate a reduction in offstream withdrawals, resulting in a shortage of water for some users. Economic, social, and environmental considerations must be weighed against overall fairness when imposing water restrictions.

Management Guidelines for Lakes

A properly managed reservoir can be a valuable asset to the State, providing a reliable supply of water, generating electricity, and offering numerous recreational and economic opportunities. An improperly managed reservoir, however, can become a liability, disrupting lake and downstream ecosystems, failing as a reliable source of water, and reducing the potential economic benefits a reservoir can offer. The goal of lake management is to satisfy as many demands as possible while protecting the resource for future use.

There are a multitude of issues facing lake managers and water resources planners. Some issues, such as water quality or allocation programs, are similar to those associated with river management. Other issues, such as hydroelectric power generation, are specific to lake management. Many problems stem from competing demands for the same limited resource. Complicating the management task is the fact that many of the reservoirs that control South Carolina's surface water system are partly or entirely located in other states. Further complicating matters is the fact that the State has little direct control over the operation of these reservoirs.

Lake Levels and Rule Curves

From the point of view of a reservoir manager (and most lake users), one of the most important operating goals is to keep the lake level at a desired elevation, usually the "full pool" level. There are many benefits to maintaining a full-pool lake level: more efficient hydroelectric power generation; consistent boating and fishing conditions; a consistent shoreline (important to lakeside property owners); and a maximized supply of water for offstream use.

Seasonal variations in the desired lake elevations are normal. Lake levels are usually lowered from full pool during the early winter in anticipation of high inflows expected during the spring. Capturing high springtime flows provides some flood protection downstream of the lake, while returning the reservoir to its full pool level. The desired, or target, lake elevation over the course of a year is known as a rule curve or guide curve. Reservoir releases are adjusted in order to keep the lake level as close to the rule curve as possible: If the lake level is too high, release more water; if it is too low, release less water.

Reservoir Release Schedules

The DNR should evaluate each regulated river in the State to determine the desired and minimum required flows just downstream from each impoundment. These flows are determined based on permitted offstream withdrawals and required instream flows. During non-drought conditions, reservoirs should be operated so that releases are sufficient to ensure that desired downstream flows are always met. During droughts, the reservoir's drought contingency plan must be activated.

Most reservoirs are obligated, by permit or license, to release a minimum flow volume over some period of time, typically one week. While these releases usually average more than the minimum required downstream flow, the timing of the releases is often highly variable: most of a week's allocation of water can be released in only three or four days (because releases are made with consideration only to hydroelectric power generation), leaving very little water for release during the remaining days of the week. Although the required weekly average release is met, instantaneous flows or average daily flows can be significantly less than the minimum required flow for several days each week. Reservoir operations should be planned to ensure adequate average daily or instantaneous flows, rather than weekly releases.

Another conflict between reservoir operations and downstream flow requirements stems from a reservoir's tendency to smooth out seasonal fluctuations in flows. To reduce a reservoir's potential negative impact on aquatic populations, consideration should be given to releasing water in such a way as to mimic natural seasonal fluctuations, where appropriate.

One of the most important issues in water resources management is balancing reservoir operations with the demands of upstream and downstream uses. Although lake uses are important, consideration must also be given to the many downstream uses as well. Specific release schedules designed to meet downstream requirements must be incorporated into the FERC license, State operating permit, or Corps of Engineers operating plan that specifies release schedules.

The State should use its authority under Section 401 of the Federal Clean Water Act to ensure that any proposed releases will not result in violations of State water quality standards, or will not result in an unacceptable degradation of water quality.

FERC Licenses—With the exception of the reservoirs operated by the U.S. Army Corps of Engineers (COE), all of the major hydropower reservoirs in South Carolina and North Carolina are licensed by FERC, the Federal Energy Regulatory Commission. FERC licenses specify operational plans, including required minimum releases. The best way to guarantee downstream flow protection is to incorporate the appropriate release conditions into the FERC licenses.

FERC licenses are usually issued for long periods of time—typically from 30 to 50 years. When licenses are reissued, changes in reservoir operating plans can be made. Relicensing, therefore, offers an excellent opportunity to incorporate strategies for managing not just the reservoir, but the entire river system, into the reservoir operating plans. Although relicensing opportunities are rare, many lakes in South Carolina and North Carolina will be relicensed within the next few years, providing important opportunities to adjust release schedules for the betterment of all the lake and river users. DNR and DHEC need to be involved in the relicensing of these reservoirs so that these rare opportunities for change are not missed.

Over time, significant changes may occur in the lake and downstream river uses, perhaps due to increasing populations or changing climatic conditions. Because of the length of time between relicensing opportunities, it is important that the reservoir operating plans detailed in the FERC licenses allow for some flexibility in reservoir operations, so that resource managers can react to changes in either water availability or demands for the water.

COE Lakes—Because the U.S. Army Corps of Engineers operates the major reservoirs on the Savannah River (Lakes Thurmond, Russell, and Hartwell), these reservoirs do not fall under the jurisdiction of FERC, and are therefore not licensed by FERC. These lakes are operated according to plans developed and implemented by the COE.

Because Georgia and South Carolina share the Savannah River lakes, both states must work together to determine downstream water demands and to incorporate appropriate release schedules into the COE operational plans. The need for this cooperation has been recognized on a political level, with the introduction of the *Savannah River Basin Compact*, a proposed (but unrealized) formal agreement between the States of Georgia and South Carolina to work together to manage the Savannah River. On a technical level, the *Savannah River Basin Comprehensive Water Resources Study* is an ongoing cooperative project between Georgia, South Carolina, and the Corps of Engineers, with the goal of balancing the many uses and demands for the entire Savannah River with the operation of the Corps' reservoirs.

The **Southeastern Power Administration** (SEPA), a division of the U. S. Department of Energy, has the responsibility to market electricity generated by the reservoirs operated by the U. S. Army Corps of Engineers in the southeastern part of the country. SEPA determines and controls the operating schedules of the Corps of Engineers reservoirs. On average, the three reservoirs on the Savannah River—Hartwell, Russell, and Thurmond—generate more than half of the total power from SEPA's ten multipurpose reservoirs within the Mobile, Savannah, and Wilmington Districts in the Southeast.

Although the **U. S. Fish and Wildlife Service** (FWS), a division of the Interior Department, does not have direct authority over reservoir operations, this agency develops and enforces legislation to protect and maintain riverine ecosystems, primarily concerning minimum required flows and habitat protection. Federal environmental laws are important in ensuring that aquatic and other ecosystems are protected. Many aquatic systems in South Carolina should be restored so that important functions of those systems can be recovered and benefits can be realized and sustained. Restoring aquatic systems does not necessarily mean returning those systems to pre-disturbance or pre-development conditions, however. State agencies should establish and maintain a strong cooperation with the Fish and Wildlife Service in order to coordinate activities relating to water resources in the State.

Water-Shortage Contingency Plans

Water-shortage contingency plans must be developed by the lake owners for all Federally-operated, FERC-licensed, or State-permitted lakes in the State. These plans should be developed and coordinated with the appropriate Federal and State agencies, local governments, and all other stakeholders, and should include water-shortage severity levels, the water releases associated with each severity level, and a public-information program. The State Drought Response Committee should approve these plans.

As long as the water level in a regulated lake is at or above the rule-curve elevation, as described in the lake's operating plan, water releases from the lake should equal or exceed the downstream desired flow requirements as defined by DNR. If the lake level declines to less than the first water-shortage severity level because of low inflow, both downstream releases and offstream lake withdrawals should be reduced.

If the volume of usable storage in a lake is reduced so much that running out of water becomes a realistic concern, downstream releases should be set equal to the inflow into the lake. By setting outflow equal to inflow, the entire volume of water remaining in the lake's usable storage becomes available for water supply use.

Uncertainty in estimates of drought severity and duration, the tolerance for water use curtailment, and the probability of system failures all need to be considered by lake managers. Drought contingency plans need to be specific to the particular uses and conditions of each lake.

Surface Water Quantity Monitoring Network

Perhaps the most important tool available to help manage the State's surface-water resources is a good monitoring network. Without an accurate knowledge of how much water is on the ground and where it is, no water resources management program can be successful.

Continuous monitoring of streamflow is necessary to collect enough flow data to develop a statistically meaningful understanding of flow regimes, and to determine accurate relationships between precipitation, soil-moisture conditions, and streamflows. These relationships are crucial for modeling and predicting future flows, in normal conditions as well as during droughts or floods.

Water quantity should be monitored in all the larger streams and lakes throughout the State. Streams originating outside South Carolina should be monitored at sites near the point of entry into the State, near midstate (Fall Line), and at sites just upstream of tidal waters. Streams located entirely within the State should be monitored at sites representative of the upper, middle, and lower areas of the Piedmont and Coastal Plain. Streams should also be monitored near sites of significant net withdrawal or discharge. In addition, many gages are installed at other locations for site-specific reasons, such as local hydrologic studies. For example, note the many streamflow gages located near the Savannah River Site (see Figure 16).

The current surface-water quantity monitoring network consists of streamflow gages, stage-only gages, and crest-stage gages (Figures 16-18). Streamflow gages continuously measure river stages, from which flow volumes are calculated, while stage-only gages continuously record lake levels and river stages without making flow calculations. Crest-stage gages record only a single high-water level resulting from a significant flood event. Many of these gaging stations operate on a near-real-time basis and as such play an important role in the State's management of extreme flow conditions. The gages in this surface-water network are operated and maintained by the USGS, with financial assistance from DNR, DHEC, and other government and private organizations.

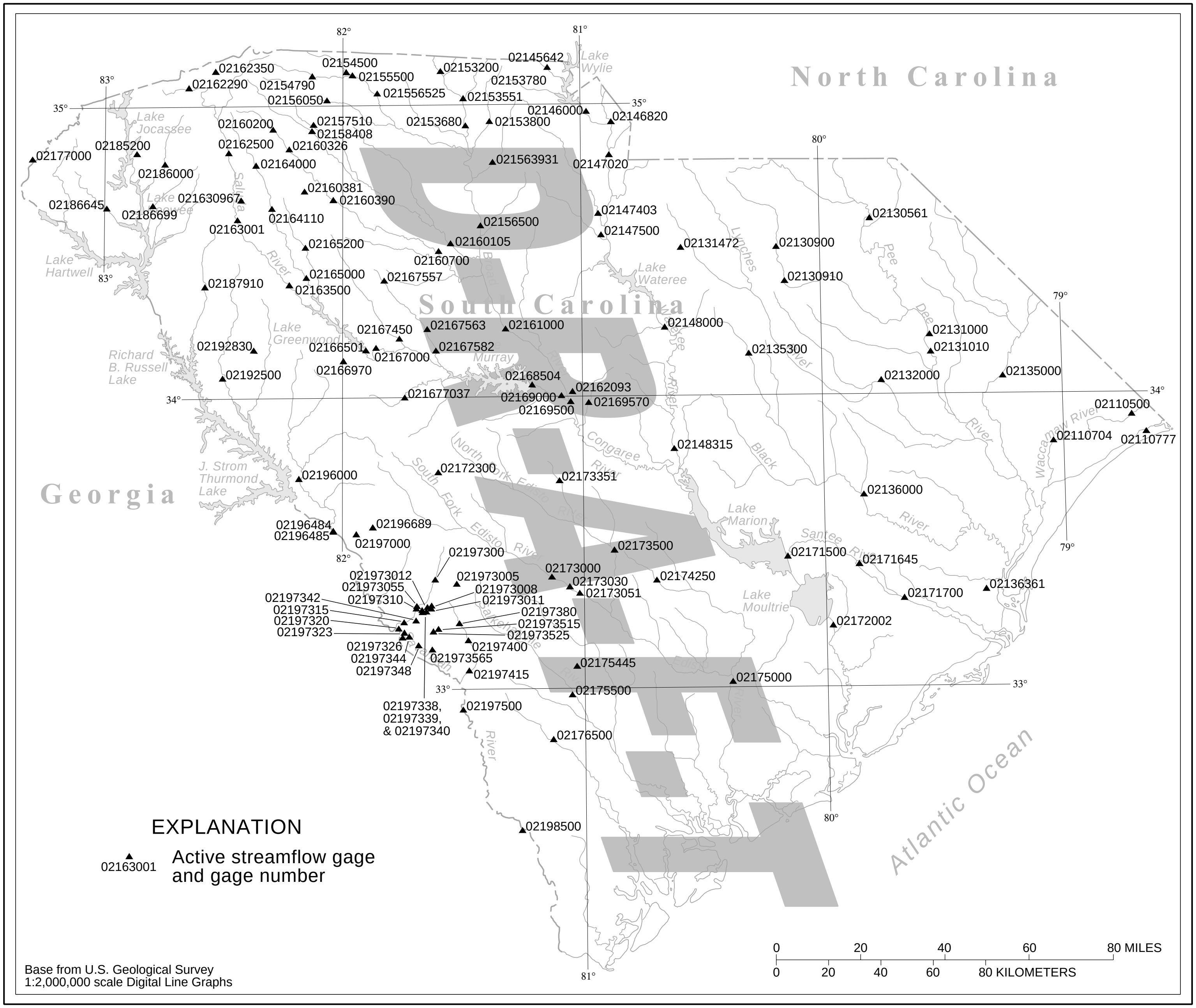


Figure 16. Current network of USGS streamflow gaging stations in South Carolina.

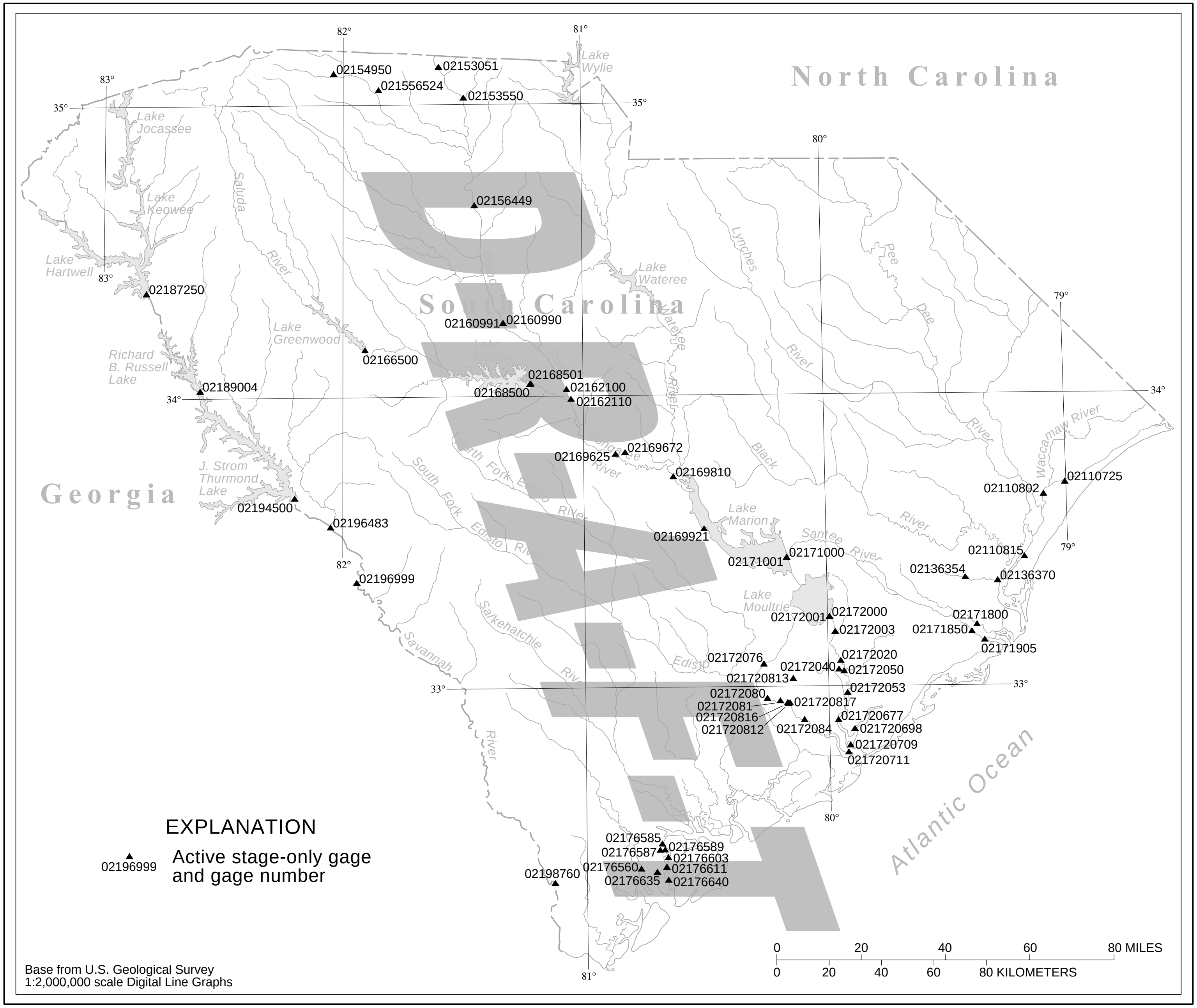


Figure 17. Current network of USGS stage-only gaging stations in South Carolina.

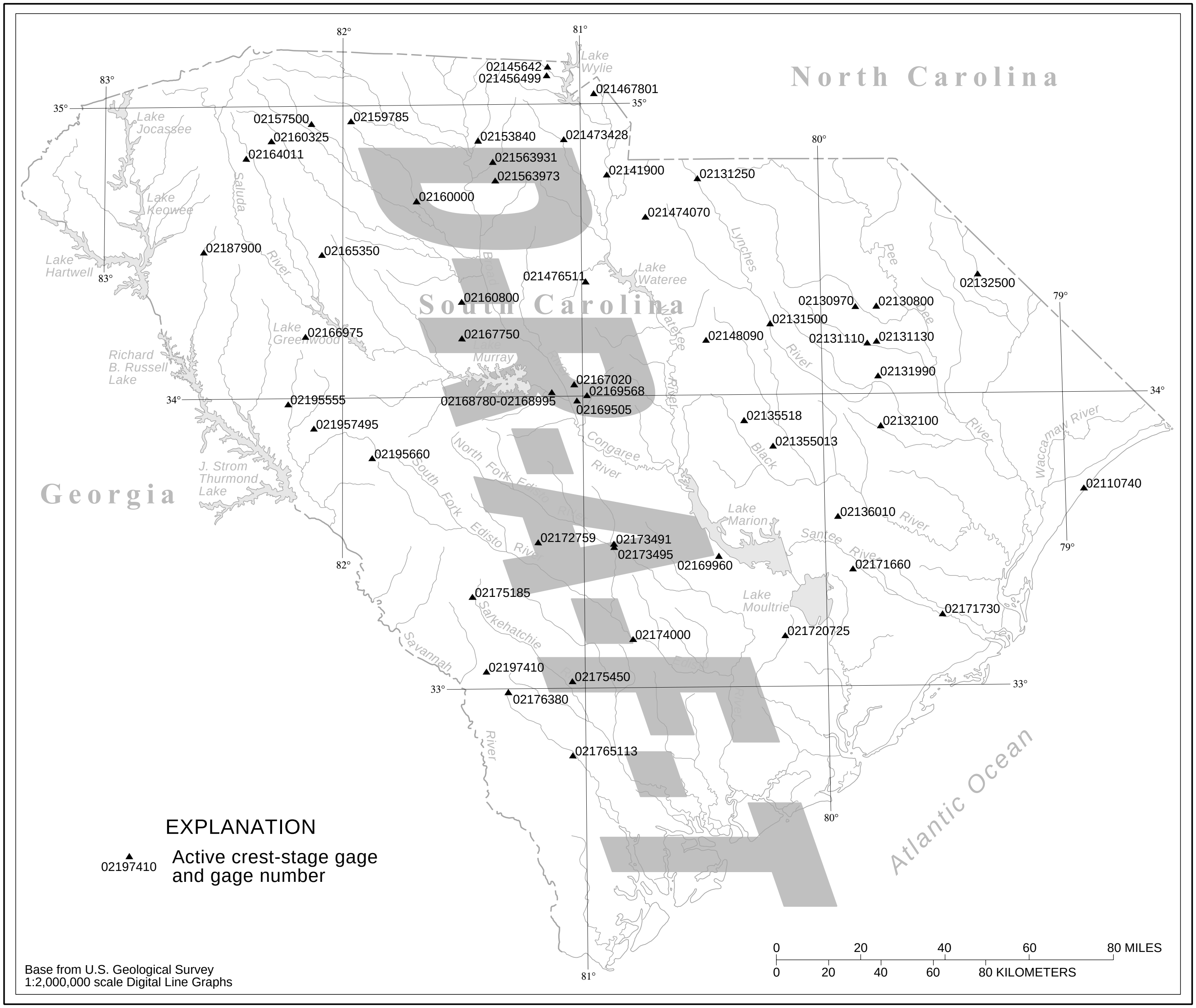


Figure 18. Current network of USGS crest-stage gaging stations in South Carolina.

Having an adequate number of properly located gages is vital to the effectiveness of this monitoring network, but it is also very important that these gages are continuously operated at the same location for a long period of time. Long-term flow records-preferably in excess of 20 years-are necessary in order to produce statistically meaningful flow histories, as well as to accurately evaluate trends in flow rates. Reduced funding has led to the elimination of several streamflow gages in each of the last few years. It is imperative that this monitoring program receives adequate funding to prevent the loss of any more gages, in particular those having been in service for many years or those installed at important locations.

SURFACE WATER QUALITY

"It is declared to be the public policy of the State to maintain reasonable standards of purity of the air and water resources of the State, consistent with the public health, safety and welfare of its citizens, maximum employment, the industrial development of the State, the propagation and protection of terrestrial and marine flora and fauna, and the protection of physical property and other resources." S.C. POLLUTION CONTROL ACT (South Carolina Code of Laws, Title 48, Chapter 1).

From agriculture and manufacturing, to recreation and tourism, clean water is essential to the economy and to the health and welfare of the citizens of the South Carolina. Over the years, Congress has promulgated and Federal and State agencies have implemented effective water quality management laws, such as the Clean Water Act and the Safe Drinking Water Act. These laws have significantly reduced surface water pollution and improved drinking water quality by regulating point source discharges and by establishing and enforcing strict standards for safe drinking water. As a result, the water in our lakes, streams, and estuaries is now cleaner than it was 30 years ago, and tap water is now safer to drink. These gains should not be lost, and a strong commitment to clean water must continue.

Polluted runoff, also known as nonpoint source pollution, is now the leading cause of water pollution in the nation and in the State. Pollutants such as bacteria and fertilizers from farms, and chemicals and oils from cities, wash into our waterways after rainstorms and adversely impact water quality. Sources of this pollution are numerous, widespread, hard to detect, and often unregulated, making them more difficult to manage than point source discharges. Preventing and reducing polluted runoff is the collective responsibility of all levels of government, agriculture, industry, landowners, and citizens alike and is best achieved at the watershed level, by enhancing stewardship, forging partnerships, and increasing public education and participation.

South Carolina Pollution Control Act

South Carolina is fortunate to have an abundance of water. Most of it is clean enough to support desired uses such as fishing and swimming. Urbanization, land development, and the extensive use of fertilizers and pesticides, coupled with increased demands for water to meet population growth and industrial and agricultural needs, place added pressures on the resource, making it increasingly difficult to meet and maintain water quality standards. Protecting, improving, and restoring water quality are goals of the State. Waters that meet State standards must be protected to ensure that quality will not be compromised in the future. Waters that do not meet standards must be restored for the intrinsic benefits that clean waters afford the citizens of the State.

The principal law governing pollution in South Carolina is the S.C. Pollution Control Act (SCPCA). In accordance with the SCPCA, the Department of Health and Environmental Control (DHEC) abates, controls, and prevents pollution of all bodies of surface and underground water, natural or artificial, public or private, inland or coastal, fresh or salt, which are wholly or partially within or bordering South Carolina or within its jurisdiction. DHEC's goal is to maintain and improve all surface waters to a level that provides for the survival and reproduction of a balanced community of plants and animals, recreation in and on the water, and, where appropriate, drinking water after conventional treatment, shellfish harvesting, and industrial and agricultural uses. Other federal and state agencies have interests and programs involving water quality protection including the S.C. Department of Natural Resource, U.S. Army Corps of Engineers, U.S. Geological Survey, as well as county and city governments.

Federal Clean Water Act

The principal law governing pollution of the nation's surface waters is the Federal Water Pollution Control Act Amendments of 1972, commonly known as the Federal Clean Water Act (CWA). The CWA provides for a variety of regulatory and non-regulatory programs to reduce direct pollutant discharges into waterways and to manage polluted runoff. Administered by the Environmental Protection Agency (EPA), the goal of the CWA is to restore and maintain the chemical, physical, and biological integrity of the nation's waters so they can support the protection and propagation of fish, shellfish, and wildlife and recreation in and on the water.

DHEC has been delegated authority by the EPA to implement the Federal Clean Water Act in South Carolina. Under Section 106 of the CWA, in order to receive funding to prevent and reduce water pollution in South Carolina, DHEC must monitor, and compile and analyze data on, surface and ground water quality.

Water Quality Standards

Under the CWA and SCPCA, DHEC is required to classify South Carolina's waters and develop water quality standards. Beneficial uses are designated for each water body and water quality standards are established that will protect the uses of the water (S.C. Regulation 61-68, *Water Classifications and Standards*). A requirement of the CWA is that State water quality standards be at least as stringent as those established by the EPA. Standards include three major components: (1) designated uses of a waterbody; (2) water quality criteria necessary to support those uses; and (3) antidegradation rules to maintain good water quality.

"Designated uses" are the desired uses of a waterbody that, at a minimum, meet the fishable/swimmable standard of the Clean Water Act. Examples of designated uses are aquatic life support, shellfish harvesting, drinking water, primary contact (swimming), and secondary contact (boating). All surface waters in South Carolina are classified on the basis of their designated uses (S.C. Regulation 61-69, *Classified Waters*), which must be approved by the South Carolina General Assembly and the EPA.

Water quality criteria describe the conditions that are necessary to support the designated uses. Numeric criteria are expressed as concentrations of pollutants, temperature, pH, turbidity units, or other numeric, quantitative measures. Narrative water quality criteria are general statements made to protect a specific designated use or set of uses.

Antidegradation policies are a set of rules that restrict or prohibit activities that could result in the degradation of high quality waters. Under provisions of the Clean Water Act, conditions of a waterbody must not be allowed to deteriorate to such a degree that one or more of the designated uses can no longer be supported. Antidegradation policies apply to point source and nonpoint sources of pollution (DHEC, 1998a and 1999a).

Water quality standards—designated uses, water quality criteria, and antidegradation policies—are the foundation of an effective water quality management program and are essential for protecting the quality of the State's surface waters. They establish water quality goals for specific water bodies and provide the regulatory basis for implementing treatment strategies to meet these goals. They are used to determine permit limits for treated wastewater discharges and any other activity that may impact water quality. Under provisions of the Clean Water Act, water quality standards are reviewed and revised every three years.

Areawide Water Quality Management Planning

The South Carolina Department of Health and Environmental Control was designated by Governor Edwards in 1976 as the State Planning Agency for water quality, and as such is responsible for Areawide Water Quality Management Planning in South Carolina pursuant to Section 208 of the CWA. Six Councils of Governments (COGs) have been designated by the Governor to provide specific areawide water quality management planning functions in areas of the state within their jurisdictions. These COGs are Appalachian, Central Midlands, Waccamaw Regional, Lowcountry, Berkeley-Charleston-Dorchester, and Santee Lynches Regional. DHEC provides specific areawide water quality management planning functions for those counties not serviced by the named COGs.

The 208 Water Quality Management Plan prepared by DHEC is updated on an as-needed basis. The process for updating or amending the plan is described within it. As the State water quality planning agency, DHEC reviews and, where applicable, certifies, approves, and submits Water Quality Management Plans and updates prepared by other areawide planning agencies to EPA for approval.

Intergovernmental and Interagency Cooperation

Enabling intergovernmental and interagency cooperation is important for several reasons. It allows for the sharing of information and expertise, helps to prevent the duplication of effort, and ensures consistency between state and federal programs. In the case of nonpoint source pollution, which does not remain within political boundaries, intergovernmental cooperation is essential. Interagency cooperation must also occur in order to streamline regulatory activities. Achieving consistency with federal programs involves cooperation with the U.S. Fish and Wildlife Service, Department of Defense, Federal Highway Administration, U.S. Geological Survey, and the National Resource Conservation Service, among others. Councils of Governments, designated management agencies, the DNR, and the S.C. Forestry Commission are key local and State partners in water quality management.

Pollution Control Programs

DHEC is authorized to implement and enforce key pollution control programs created by the Federal Clean Water Act. Five of the most important of these programs are described below:

Section 303(d) (Total Maximum Daily Load)—Section 303(d) requires states to identify waters that are impaired in spite of effluent limitations. For these water bodies, a TMDL must be developed for the pollutant(s) causing the water quality violation. The TMDL includes both nonpoint sources (load) and point sources (wasteload) of pollutants in the calculations used to determine how much of the pollutant can be assimilated by the receiving body of water. The TMDL must also include a margin of safety. TMDLs are developed by the DHEC's Bureau of Water, approved by EPA and then implemented by reissuing or modifying permits, and through voluntary pollution reduction measures.

Every two years the State is required to inventory and list impaired water bodies and develop TMDLs for these waters where appropriate. States are asked to include *threatened* good quality waters in their identification of waters still needing TMDLs, and required to identify high priority waters targeted for TMDL development over the next two years.

Section 402 (National Pollutant Discharge Elimination System)—Section 402 of the Clean Water Act creates the National Pollutant Discharge Elimination System (NPDES). All facilities that discharge pollutants from any point source to waters of the United States must obtain a permit through the NPDES. These permits state the limits placed on discharges, as well as monitoring and reporting requirements. Any permit limit must be stringent enough to ensure that the discharge will not cause a violation of the water quality standards. NPDES permits are issued for a period of up to five years.

DHEC will not issue an NPDES or wastewater construction permit unless it has been certified by the applicable areawide water quality management agency that the permit will be consistent with the applicable plan. South Carolina has six separate areawide wastewater treatment plans as described in the 208 Water Quality Management Plan produced by DHEC. This document describes how agencies are authorized to administer wastewater issues. It also provides an inventory of the publicly-owned wastewater treatment works (POTWs) in the area of the state where DHEC provides specific areawide water quality management functions.

Residual waste is the solid material, or sludge, remaining after wastewater treatment. Disposal and use of sludge is regulated by DHEC's Bureau of Water as part of the NPDES or land application permitting process.

Section 319 (Nonpoint Source Pollution Program)—Section 319 of the Clean Water Act requires the State to produce a nonpoint source pollution (NPS) assessment report and to develop a statewide NPS pollution management program.

NPS is the leading cause of water pollution in the nation and in the South Carolina. The State's NPS Assessment Report describes existing and potential NPS problems for over 300 water bodies in the State. To address this growing problem, the S.C. NPS Management Program was developed by DHEC, approved by the EPA in 1990 and was updated in 1999. The NPS Management Program provides a framework for managing NPS pollution and for restoring water bodies impacted by it. It relies on regulatory and non-regulatory programs and on the implementation of Best Management Practices (BMPs).

Water pollution caused by atmospheric (wind-borne) deposition is a growing problem in the Nation. The National Air Deposition Program monitors mercury, nitrogen compounds, phosphate, sulfur oxides, and acid rain at over 200 stations nationwide, five of which are located in South Carolina. Mercury is a naturally occurring element that is commonly found in coal. When coal is burned at power plants, mercury is emitted with the smoke and is directly deposited in water bodies or runs off the ground into the water. Microorganisms convert elemental mercury to methylmercury, a highly toxic form of mercury, which accumulates in fish tissue. Samples collected from blackwater streams in the Santee Basin by the USGS indicate that they had the greatest ratio of methylmercury to total mercury in the Nation (Hughes and others, 2000). This suggests that conditions in the Santee Basin are conducive to converting a relatively small amount of elemental mercury into high concentrations of methylmercury. Additional studies should be conducted that address the high levels of methylmercury concentrations found in fish tissue samples in the State.

Section 401 (Water quality certification)—Section 401(a) of the Clean Water Act requires that an applicant must receive certification from the State before it can receive a federal license or permit to conduct an activity that results in discharge into navigable waters of the State.

This section provides protection around and downstream from federally permitted projects, such as hydroelectric generation. Applications for wetland alterations can be denied under provisions of this section. Certification issued by the State is contingent upon meeting water quality standards. S.C. Regulation 61-101 (*Water Quality Certification*) establishes procedures and policies for implementing certification.

Section 404 (Placement of dredged materials into waters)—Under Section 404 of the Clean Water Act, a federal permit is required to discharge dredged or fill material into waters of the United States, including wetlands. This program is administered jointly by EPA and the U.S. Army Corps of Engineers, but the federal permit cannot be issued if the State (DHEC) denies 401 water quality certification.

Activities that are regulated under this program include fills for development, water resource projects (such as dams and levees), infrastructure development (such as highways and airports), and conversion of wetlands to uplands for farming and forestry. No discharge of dredged or fill material is permitted if a practical alternative exists that is less damaging to the environment or if the State's waters would be significantly degraded.

Wetlands contribute to the health and safety of the public by controlling floods and by intercepting and storing polluted stormwater runoff before it reaches other waterways. They also serve as important habitats for plants and animals. Small, isolated freshwater wetlands in the State continue to be lost to development by either being filled or ditched. At the present time, the State has no authority to prevent this from occurring. The State must remain committed to the protection and restoration of its wetlands and to the concept of no net loss of wetlands.

Watershed-based Water Quality Management

A watershed is a geographic area into which rivers and tributaries drain, and whose boundaries are marked by surrounding topographic highlands. In 1998, President Clinton released the "Clean Water Action Plan", a watershed approach to protecting and restoring the nation's water resources. This approach focuses all management activities—such as monitoring, assessment, NPDES permitting, and TMDL restoration studies—within a single, high-priority watershed. Such an approach recognizes that water pollution in a watershed is a function of land-use activities that are occurring in the watershed. It also fosters stewardship and volunteerism by allowing stakeholders to participate in decisions and actions that will protect and restore the watershed in which they work and live.

In 1991, DHEC implemented the State's Watershed Water Quality Management Strategy to increase the efficiency and effectiveness of programs that protect and improve the quality of South Carolina's surface and ground water resources. The strategy recognizes the interdependence of water quality and all the activities that occur in the associated watershed. Water quality monitoring, assessment, modeling, planning, permitting and other DHEC initiatives are coordinated within the framework of a watershed management approach.

Watershed Water Quality Assessment reports are prepared for all of the major river basins on a five-year rotating basis. These comprehensive reports include information about a watershed's water chemistry, biological monitoring, physical characteristics, natural resources, growth potential, potential nonpoint source contributions, ground water concerns, and point source discharges.

Water Quality Planning

Section 303(e) of the CWA requires that each state establish and maintain a continuing planning process (CPP) consistent with the Act. The CPP explains South Carolina's approach to implementing Federal and State laws and regulations on water quality. It describes processes for developing and updating water quality management program elements, purpose, and implementation and public participation requirements. DHEC is responsible for routinely updating South Carolina's CPP.

Programs of the U.S. Geological Survey

As the primary Federal science agency for water-resource information, the U.S. Geological Survey (USGS) monitors the quantity and quality of water in the Nation's rivers and aquifers. The Cooperative Water Program has been a successful cost-sharing partnership between the USGS and water-resource agencies at the State and local levels. Most work in the Cooperative Water Program is directed toward potential and emerging long-term problems, such as water supply, waste disposal, ground-water quality, effect of agricultural chemicals, floods, droughts, and environmental protection.

The National Water Quality Assessment Program (NAWQA) is a USGS program that collects and assesses information on water chemistry, hydrology, land use, stream habitat, and aquatic life from more than 50 major river basins and aquifers across the nation. This information supports the development and evaluation of management, regulatory, and monitoring decisions by other Federal, State, and local agencies, and assesses water quality conditions nationwide.

The USGS Toxic Substances Hydrology Program was initiated in 1982, with the goal of providing scientific information on the behavior of toxic substances in the Nation's hydrologic environments. Investigations occur over a wide range of scales, from point sources, such as leaks or discharges from industrial facilities; to multiple, closely spaced releases, such as domestic septic systems; to relatively uniform releases that occur over broad areas, such as agricultural and residential land uses.

Drinking Water

The Safe Drinking Water Act (SDWA) of 1974 authorizes the EPA to set national health-based standards for drinking water to control the levels of naturally occurring and manmade contaminants in the nation's drinking water supply. These standards are a key component of the EPA's comprehensive approach to drinking water protection, which includes assessing and protecting drinking water sources; protecting wells and collection systems; making sure water is treated by qualified operators; ensuring the integrity of distribution systems; and making information available to the general public about the quality of their drinking water. Under provisions of the Federal Safe Drinking Water Act, EPA authorized DHEC to implement and enforce programs of the SDWA to ensure that the public water systems in the State provide safe drinking water.

Amendments to the SDWA in 1996 place a priority on prevention activities as an approach to improving drinking water supplies. The amendments require the State to provide Source Water Assessments for each federally defined public water supply system. These assessments include the *Source Water Protection Area (SWPA)*—a description of the drinking water source and the land area that contributes water to that source; a *Potential Contaminant Source Inventory*—a listing of the land uses and activities within the SWPA that could potentially release contaminants to the source water; and a *Susceptibility Analysis*—an evaluation of the contaminant inventory to determine the likelihood that a potential contaminant source will affect a nearby drinking water source. These assessments should be used by public water systems to determine what preventive actions are needed to protect drinking water sources from contamination.

The "Capacity Development" initiative requires states to develop and implement a strategy to ensure that all public water systems have the technical, managerial, and financial capability to reliably deliver safe water to the public, and a plan to identify and assist those water systems that need improvements. South Carolina had already initiated such an effort in 1993 and received early approval from the EPA. Components of the program include construction permitting requirements for new water systems or for modifications or expansions of existing systems; sanitary surveys that evaluate a system's technical, managerial, and financial capacity to comply with the State SDWA; and an operating permit program requiring systems that fail sanitary surveys to prepare and submit a business plan to DHEC. To strengthen drinking water safety, DHEC has the legal authority to deny business plans or construction permits to any public water system that is unable to demonstrate the capacity to comply with State drinking water standards.

States are required to submit an annual report on public water system violations to EPA. These reports must address violations of drinking water standards with respect to maximum contaminant levels, treatment techniques, monitoring requirements, and variances and exemptions. As of 1999, all community water systems are required to prepare and distribute an annual "Consumer Confidence Report" documenting the quality of water delivered by the system. The report includes information about the type of contaminants that were detected and the health risks associated with those contaminants. Public water systems must also notify their customers when they violate EPA or state drinking water standards. Any violation of a standard "that has the potential to have serious adverse effects on human health as a result of short-term exposure" must be reported within 24 hours.

Surface Water Quality Monitoring Networks

The Clean Water Act of 1972 gives states the primary responsibility for implementing programs to protect and restore water quality, including monitoring. Under the provisions of both the South Carolina Pollution Control Act and the Clean Water Act, DHEC is the State agency delegated with the responsibility of monitoring the quality of water in the State's streams, lakes, and estuaries. Monitoring is done in order to determine water quality status and trends, identify emerging water-quality problems, identify water bodies that are not supporting designated uses, determine if remediation and management programs are effective, issue permits for effluent discharge and determine if dischargers are in compliance with pollution regulations, and evaluate the impacts of environmental emergencies such as spills.

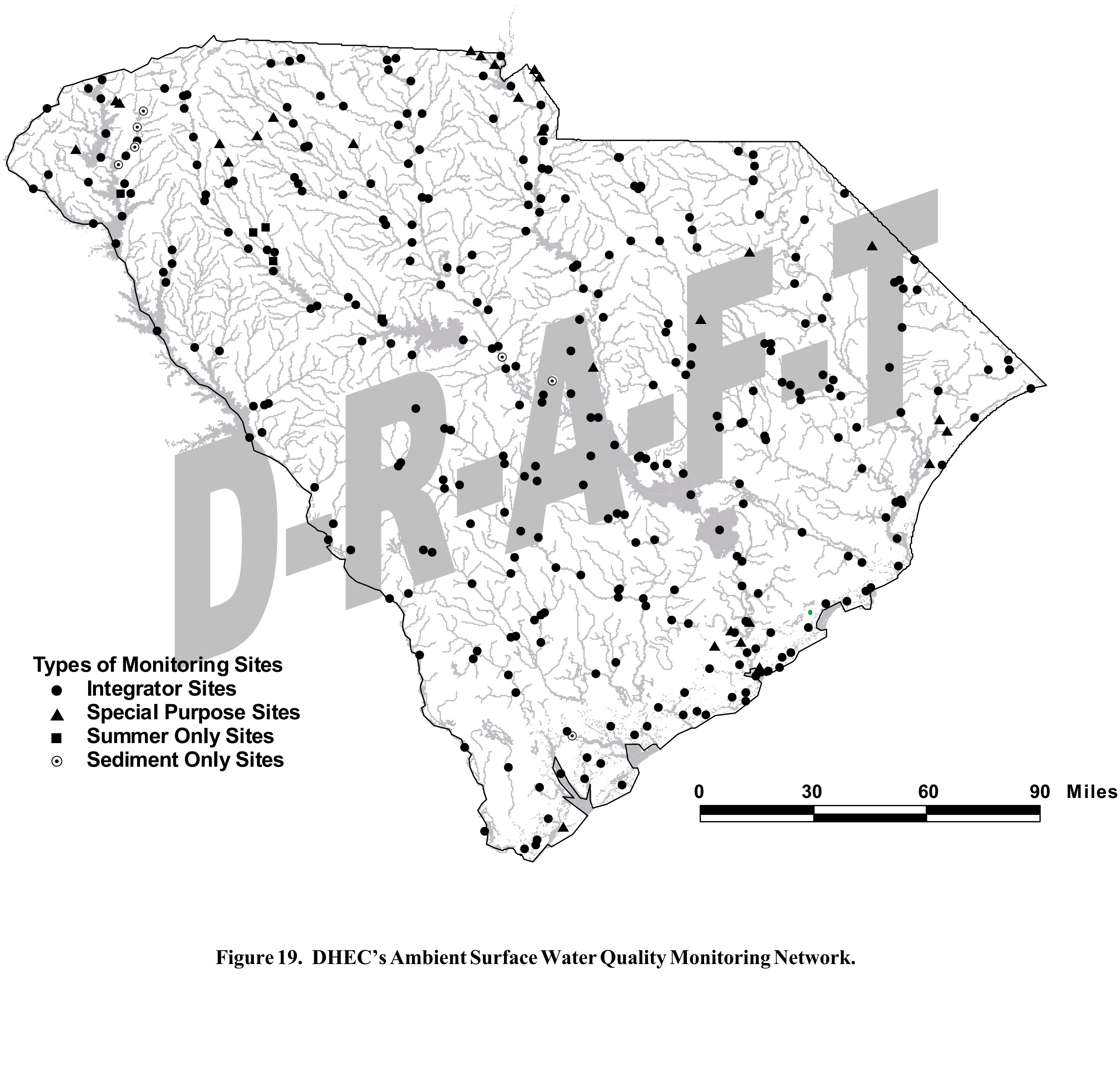


Figure 19. DHEC's Ambient Surface Water Quality Monitoring Network.

The primary monitoring network in the state is the Ambient Surface Water Quality Monitoring Network. This network, operated by DHEC, is used to assess the overall physical, chemical, and biological integrity of the State's streams, lakes, and estuaries. The core of this statewide network consists of Integrator Sites, which are 314 permanent, fixed-location monitoring sites that are sampled once per month, year round, every year (Figure 19). Sites are targeted for the most downstream access of each of the Natural Resource Conservation Service 11-digit watershed units, as well as the major lakes, reservoirs, and estuarine areas within each watershed unit.

Special Purpose Sites of the ambient network are also permanent, fixed-location sites but do not meet the location criteria of the Integrator Sites (Figure 19). These sites represent locations that are of special interest to the State, such as areas used to track the progress of specific remediation activities, or where additional data is needed in large watersheds. Currently there are 30 Special Purpose Sites sampled once per month, year-round, every year.

Watershed Water Quality Management Sites constitute a monitoring network that supplements the Integrator and Special Purpose stations on a 5-year rotating schedule (Figure 20). Each major watershed is sampled once every five years to provide additional information for various programs and to assess results of remediation activities. There are about 80 to 100 monitoring sites within a given watershed, sampled once per month for an entire year.

A statewide random sampling of streams, lakes, and estuaries is done each year as part of the Ambient Surface Water Quality program. These samples are collected in order to make statistically valid statements about the water quality of large areas on the basis of a relatively small subset of sampling points. Each year, approximately 30 randomly selected sites are sampled in streams, 30 sites are sampled in lakes or reservoirs, and 30 sites are sampled in estuaries. Each of these sites is sampled monthly for one year. The 30 estuarine sites correspond to the South Carolina Estuarine and Coastal Assessment Program Core Sites, described below.

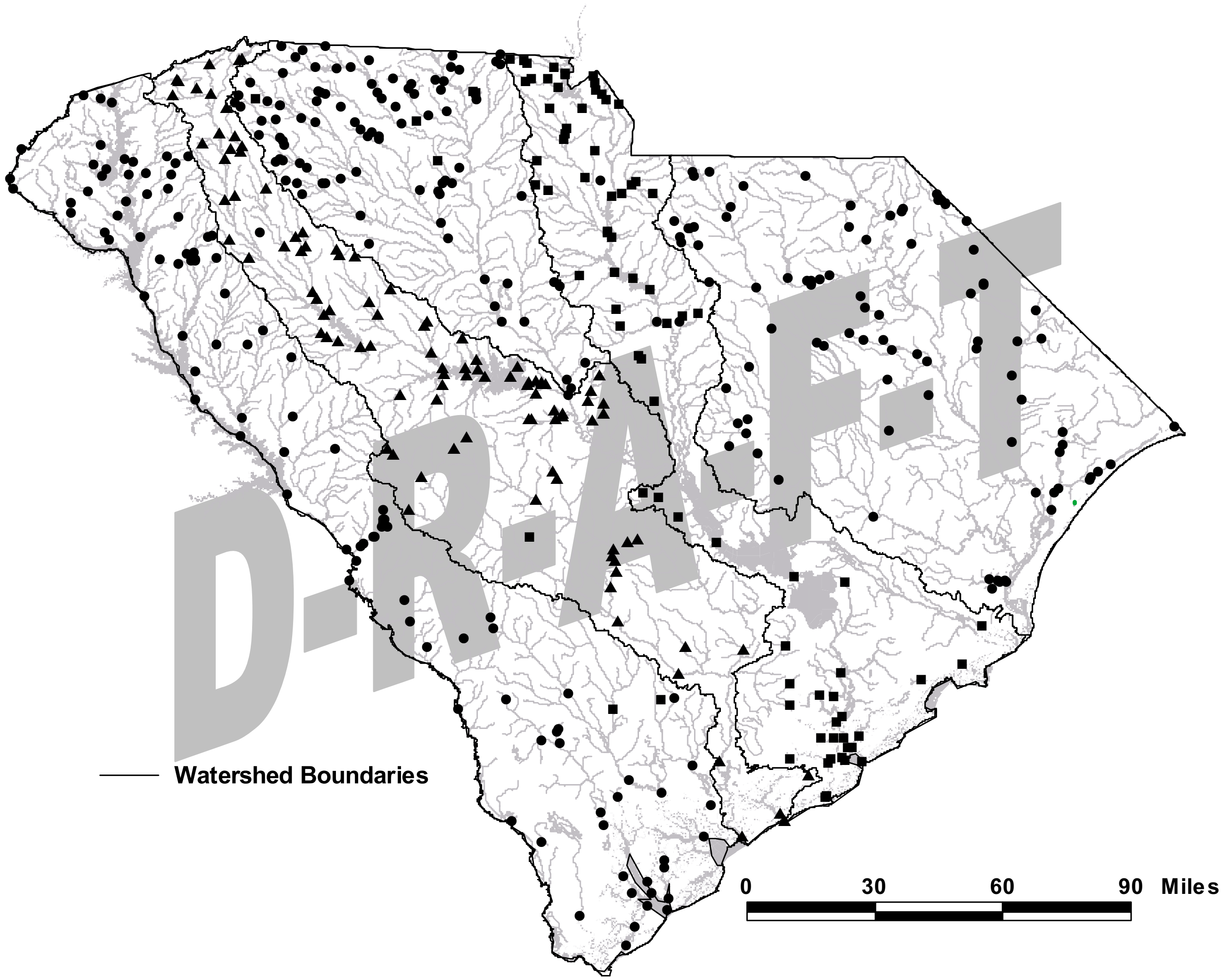


Figure 20. DHEC's Watershed Water Quality Monitoring Network.

The South Carolina Estuarine and Coastal Assessment Program was developed by DHEC, DNR, and the Marine Resources Research Institute (MRRI) to assess water quality of coastal estuaries. Water samples at 30 Core Sites in tidal creeks and open-water environments are sampled monthly by DHEC as part of the Ambient Surface Water Quality Monitoring Network. Sediment samples at the Core Sites are collected annually by DNR and MRRI for sediment chemistry and toxicity analyses. Sediment and water samples are also collected from 30 Supplemental Sites on a yearly basis.

Pollutants that are discharged at low concentrations or during storm runoff events may be undetectable or absent during normal sampling intervals. These pollutants bind to organic matter in the water column and settle to the bottom where they become part of the sediments composing the streambed. Sediment samples are collected at each randomly selected site, as described above, and at 87 permanent, fixed-location sites and analyzed for the presence of pollutants.

In the course of a complete five-year Watershed cycle, data are collected at more than 1,250 monitoring locations across the State through the Ambient Surface Water Quality Monitoring Network.

The Ocean Water Monitoring program is administered by DHEC and is designed to protect the health of beachgoers. Water samples are collected from 112 sites along the coast on a monthly basis from April through October and on a bi-weekly basis from May through September. Samples are also collected after rain, sewage spills, or excessively high tides. Swimming advisories are issued if samples are found to contain elevated counts of bacteria.

The U.S. Geological Survey maintains a network of water quality stations near several of their stream gages (Figure 21). Continuous-record stations at fixed locations record water-quality parameters on a regularly scheduled basis, where the frequency of sampling can be one or more times daily, weekly, monthly, or quarterly. Partial-record stations are maintained at fixed locations for a period of years but record limited water-quality data

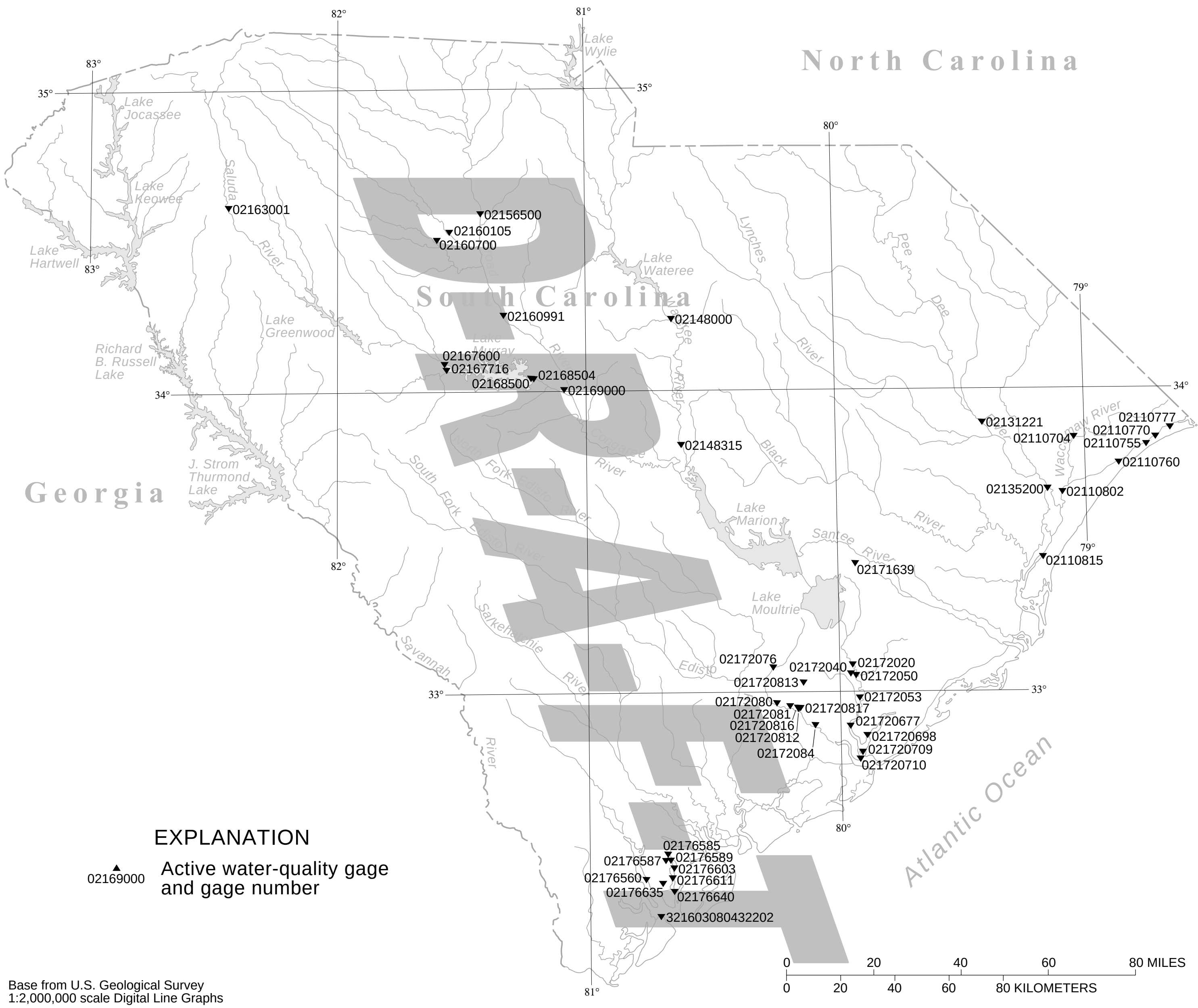


Figure 21. Current network of USGS surface water quality stations in South Carolina.

at a sampling interval that is usually less than quarterly. Other stations collect random samples from locations other than the continuous- and partial-record sites. Parameters measured at these stations generally include water temperature, specific conductance, dissolved oxygen, pH, and turbidity.

GROUND WATER QUANTITY

Ground water is a significant source of drinking water in the State, supplying about 40 percent of the population, including virtually all of the rural population. It is also an important source of water for manufacturing, irrigation, and power generation and is vital for maintaining aquatic ecosystems by recharging streams, lakes, and wetlands and for sustaining surface water supplies during droughts. In fact, about 60 percent of the water in our streams originates as ground water.

Aquifers of South Carolina

Ground water occurs everywhere in the State but is most abundant in the Coastal Plain. The Coastal Plain province consists of unconsolidated layers of sand, clay, and limestone that thickens from zero feet at the Fall Line to about 3,800 feet near Hilton Head Island. Sand and limestone layers are porous and constitute the aquifers of the Coastal Plain; clay layers are relatively impervious and constitute the confining units.

Aquifers bounded above and below by clay layers are called confined aquifers, and wells penetrating such aquifers are referred to as artesian wells. Water in confined aquifers is under high pressure and rises in a well above the top of the aquifer. Wells that flow to land surface are referred to as flowing artesian wells. Confined aquifers of the Coastal Plain are hydraulically continuous and can be mapped for tens, and even hundreds, of square miles.

Shallow aquifers that lack confinement are called unconfined or water-table aquifers, and wells tapping such aquifers are referred to as water-table wells. Water in unconfined aquifers is under normal atmospheric pressure and only rises in a well to the top of the saturated zone, which is known as the water table. Water-table aquifers occur throughout the Coastal Plain province but locally discharge to streams and other surface water bodies, thereby limiting their lateral continuity and size.

The Piedmont province consists of hard, practically impermeable metamorphic and igneous rocks overlain by a layer of loose sand and clay called saprolite. Saprolite is the weathered byproduct of Piedmont rocks and serves as a storage reservoir for ground water in the province. Although relatively impervious compared to Coastal Plain deposits, saprolite slowly transmits water to the underlying rocks through a system of fractures that extends from the base of the saprolite to the unweathered rocks.

Water in the saprolite is generally under normal atmospheric pressure; as such, wells constructed in saprolite are similar to water-table wells of the Coastal Plain. For the purposes of this report, both the unconfined aquifers of the Coastal Plain and the saprolitic layer of the Piedmont are considered to be the water-table aquifers of the State.

Water that occurs in the fractured bedrock can either be under normal atmospheric pressure or high pressure. However, unlike confined aquifers of the Coastal Plain, fracture zones are only connected over short distances; therefore, there is little hydraulic continuity to the aquifers of the Piedmont province. Wells constructed in the fractured bedrock are referred to as rock wells, and the aquifers they tap are collectively called bedrock aquifers.

Groundwater Use and Reporting Act

The principal law governing the management of ground water quantity in the State is the Groundwater Use and Reporting Act (Title 49, Chapter 5), which states "that the general welfare and public interest require that the groundwater resources of the State be put to beneficial use to the fullest extent to which they are capable, subject to reasonable regulation, in order to conserve and protect these resources, prevent waste, and to provide and maintain conditions which are conducive to the development and use of water resources."

The act also establishes conditions for the designation of Capacity Use Areas: "In the State where excessive groundwater withdrawal presents potential adverse effects to the natural resources or poses a threat to public health, safety, or economic welfare or where conditions pose a significant threat to the long-term integrity of a groundwater source, including salt water intrusion, the board, after notice and public hearing, in accordance with the Administrative Procedures Act, shall designate a capacity use area."

The Capacity Use Permitting Program requires permits for large-scale (3 million gallons or more in any month) ground water withdrawals in designated Capacity Use Areas. Each permit must comply with the construction, operation, and special conditions as set forth in the regulations. DHEC has the authority to modify, revoke, or deny permits and can set limits on pumping rates and on the number of wells withdrawing from an aquifer.

Ground Water Programs

The "hidden resource," ground water is difficult to understand because it can't be seen at the surface. Consequently, our knowledge of ground water lags behind our knowledge surface water. Water wells offer the primary means of understanding ground water. Although tens-of-thousands of wells have been drilled in the State, the vast majority of them are shallow, often less than several hundreds of feet deep. Few wells have geology or geophysical logs, and fewer have pumping tests or cores.

The USGS, DNR, and DHEC all play key roles in the collection, management, and analysis of ground water data. Advancing our knowledge of this resource must continue with routine data collection, county and statewide ground water investigations, and with programs like the Surface Geophysics (WADI) and Borehole Geophysical Logging Programs. State colleges and universities should play a larger role in addressing State ground water issues. New test holes should be drilled in areas that lack substantial subsurface data.

Geophysical logs are an important source of subsurface data and are used for delineating aquifer boundaries, assessing water salinity, and determining well-screen locations to optimize ground water development. Efforts should be coordinated between DHEC and DNR to ensure that geophysical logs are obtained from new public-supply wells in areas of the State where they are needed.

A key to understanding the ground water resources is having accurate information about the location, thickness, and continuity of aquifers and confining units. The DNR, in cooperation with the USGS and DHEC, should reevaluate the existing hydrogeologic framework and improved it where necessary. Aquifers and confining units should be delineated, mapped, and characterized with respect to their hydraulic properties. Recharge areas should be delineated and characterized. New water wells and test holes should be incorporated into the framework on an ongoing basis to continually improve the accuracy of the framework. Well cluster sites are needed to understand the vertical head relationships and the vertical hydraulic gradients between aquifers.

Computer flow models can be powerful management tools for allocating and optimizing ground water withdrawals, and for evaluating conjunctive use strategies and interactions between ground water and surface water. A comprehensive ground water flow model of the Coastal Plain should be developed by the USGS, in cooperation with DNR and DHEC. The model should incorporate the best scientific data available and should be revised periodically as new data or modeling techniques warrant.

Accurate water use data is an important consideration when developing a ground water management plan and for evaluating water use trends. Historically, only large ground water users in Capacity Use Areas were required to report their water use. The Groundwater Use and Reporting Act was amended in 2000 requiring anyone in the State who withdraws 3 million gallons or more in any single month to register and annually report their water use to DHEC. This applies to ground water users in Capacity Use Areas and those outside Capacity Use Areas. This program should be strictly enforced to ensure compliance with metering requirements and reporting requirements. Unscheduled field checks should be made to ensure compliance.

Because the State does not have the financial resources to drill the number of deep wells that are needed to implement and maintain the Potentiometric Mapping Program and other ground water investigations, existing municipal, irrigation, industrial, and other deep wells are used in these programs. These non-State-owned wells are sometimes abandoned by their owners when the wells are no longer needed or used, resulting in the permanent loss of the wells and of any future information they might provide. To prevent such losses, the DNR and USGS should be given 60 days advance notice of any well that is being considered for abandonment. If deemed important to the State's ground water monitoring programs, a variance should be granted to keep wells from being permanently plugged. In all other cases, wells should be abandoned in accordance with the law as described in the State Primary Drinking Water Regulation (S.C. Regulation 61-58) and in the Well Standards (S.C. Regulation 61-71).

Regulating Ground Water Withdrawals

Although ground water is a renewable resource, pumping water from wells at rates that exceed natural replenishment can deplete the resource and cause ground water levels to decline. Consequences of over-pumping include reductions in well yield, increased pumping costs, reduced flow rates in rivers, altered ground water flow patterns, water-level declines in lakes and wetlands, land subsidence, sinkholes, and salt water intrusion and encroachment.

Cones of depression (regional water-level declines) develop in areas where aquifers are being stressed by excessive, long-term pumping. When water is pumped from a well, the water in the well begins to drop and is replaced with water from the aquifer. As pumping continues, water levels in the aquifer continue to decline and take on the shape of a cone, the apex of which is centered at the well. This "cone of depression" radiates outward from the well. Water levels are at their deepest near the well and gradually lessen away from the well.

Identifying and mapping the extent of these cones is critical for evaluating ground water conditions. Potentiometric maps of each major aquifer in the State should be constructed at least every five years to identify those areas where over-pumping is occurring and to determine how conditions are changing with time. Potentiometric maps should be used to detect changes in aquifer storage by evaluating the expansion or contraction of cones, and to assess the effectiveness of ground water management practices.

Over-pumping has caused significant regional water-level declines in nearly half (13) of the counties in the Coastal Plain. Declines have been documented in Beaufort, Berkeley, Charleston, Colleton, Darlington, Dorchester, Florence, Georgetown, Horry, Jasper, Marion, Sumter and Williamsburg Counties. Cones of depression can impact large areas, affect hundreds of well owners, and can take decades to recover. For example, separate cones of depression in Georgetown and eastern Williamsburg Counties have coalesced to form a large cone that covers an area of about 700 square miles; water levels in that area have declined more than 200 feet from predevelopment levels (Hockensmith, 2003b).

Although cones of depression are reversible—reduced pumping will result in a return to higher water levels—significant over-pumping of an aquifer can also cause permanent damage to the aquifer or the overlying land. The water level in a confined aquifer can decline to a point at which the increased stress on the aquifer system causes a rearrangement of the grains that form the aquifer skeleton, resulting in an irreversible reduction in the aquifer's water-storing capacity. Excessive over-pumping can also lead to the dewatering of clay layers within the aquifer system, which can cause land subsidence. This is of particular concern in South Carolina because of the large number of clay beds in the Coastal Plain aquifer systems. In areas of the State that are underlain by limestone aquifers, water level declines can cause a sudden collapse of land surface, resulting in sinkholes.

Land subsidence caused by ground water withdrawal accounts for 80 percent of the subsidence documented in the nation (Galloway and others, 1999) and has been reported in South Carolina (Spigner, 1978; Hockensmith, 1989). Although some lowering of land surface may be acceptable in some areas, it could be devastating in other areas of the State, especially near the coast. A study should be made by the DNR and the S.C. Geodetic Survey to determine if, and to what extent, subsidence has occurred in the Coastal Plain.

To protect aquifer systems and to ensure the long-term sustainability of the ground water resources, the entire Coastal Plain province should be designated a Capacity Use Area. This permits the State to increase mandatory monitoring of the resource and to regulate ground water withdrawals. Currently, only the coastal counties and a small portion of southern Marion County have been designated as Capacity Use Areas.

One of the major issues concerning ground water management is the determination of when withdrawal restrictions should be activated. The 1998 Water Plan called for a single Trigger Level for each aquifer in the State: 150 feet of drawdown for the Black Creek and Middendorf aquifers, and 75 feet for the Floridan aquifer. When the water level in an aquifer drops below the Trigger Level, restrictions would be activated. Such widespread and generalized Trigger Levels may prove ineffective because of local variations in the aquifer systems. For example, during the 1998-2002 drought, irrigation wells in several counties were partly responsible for impacting private wells long before aquifer water levels approached the Trigger Levels. The 1998 Trigger Levels should continue to be used as the maximum limit to which water levels are allowed to decline before withdrawal restrictions are imposed. Further studies should be made to refine these Trigger Levels throughout the Coastal Plain.

An adaptive management strategy may provide a much more effective means of regulating the resource because it would not rely solely on a single trigger mechanism to initiate withdrawal restrictions. Ground water allocation programs should consider localized hydrogeologic factors, such as aquifer transmissivity and vertical hydraulic gradients, to determine when withdrawal restrictions are needed. Resource managers should develop policies—such as mandatory well spacing, or the declaration of certain aquifers as "domestic use only"—to minimize the need for restricted withdrawals.

Procedures and guidelines for aquifer and ground water management should address the following goals:

1. Withdrawals should be managed so as to minimize their impacts on other users of the aquifer. Large-capacity wells should be placed suitably far from existing domestic wells, and they should not be screened or gravel-packed in aquifers used primarily for domestic supply.

2. Withdrawals should be managed so as to minimize degradation of aquifer water quality.

3. Withdrawals of water from an aquifer should not result in saltwater intrusion or encroachment. Withdrawal locations should be sufficiently inland so as not to exacerbate existing intrusion, but to aid in its elimination.

4. Withdrawal rates should be managed so as to prevent subsidence of the land surface and sinkholes at all locations.

5. Withdrawals from water-table aquifers should be managed with consideration for the impact these aquifers have on wetlands, floodplains, saltwater intrusion, surface water bodies, and confined aquifers.

6. Withdrawals from aquifers that have significant water-level declines should be restricted so as to minimize further declines or to reverse declines. Ground water flow models should be developed and used to predict the effect of future pumping scenarios and to determine optimal well spacings. Conjunctive use strategies and alternative sources of water should be considered.

7. Withdrawals should be managed to make the most efficient use of the water.

8. Withdrawals during droughts should be managed to protect drinking water supplies obtained from public supply wells or private domestic wells. Withdrawals used for other purposes may have to be reduced or curtailed to ensure adequate drinking water supplies.

Ground Water Quantity Monitoring Networks

Ground-water quantity should be monitored in the Coastal Plain and Piedmont provinces to determine the overall effects that pumping and drought have on the State's ground-water resources. Monitoring wells are equipped with automated, digital water-level recorders that measure and record depth to the water level, usually on an hourly basis. Data stored on the recorders are compiled on a quarterly basis, and hydrographs are constructed annually showing water-level changes and seasonal fluctuations of each aquifer. Changes in storage can be evaluated to determine the general conditions of the ground-water resources of the State.

Seven confined aquifers can be delineated and mapped across the Coastal Plain. In each county, water levels in a minimum of two wells per aquifer should be monitored with automatic data loggers. In those counties where water-level declines have been documented, or where a single aquifer is heavily utilized, a minimum of three wells should be monitored per aquifer. Monitoring wells should have screens set adjacent only to the aquifer that is being monitored; individual wells with screens set adjacent to several different aquifers should not be included in the monitoring network. Figure 22 shows the current ground-water monitoring network for the confined aquifers of the Coastal Plain, and Table 4 lists the number of additional wells required to complete the network.

In addition to the confined aquifers of the Coastal Plain, water levels in a minimum of one well per county should be monitored in the bedrock aquifers of the Piedmont province using automatic data loggers. The current ground-water monitoring network for the bedrock aquifers of the Piedmont province is also shown on Figure 22, and Table 4 lists the number of additional wells required to complete this Piedmont network.

Owing to their shallow depths and low yields, water-table aquifers typically are not used as a source for water-supply systems; however, they are important because they contribute significantly to baseflow; they are in direct communication with other surface-water bodies such as wetlands, springs, streams, ponds, and lakes; and they recharge the deeper, confined aquifers. Water levels in water-table aquifers reflect soil-moisture

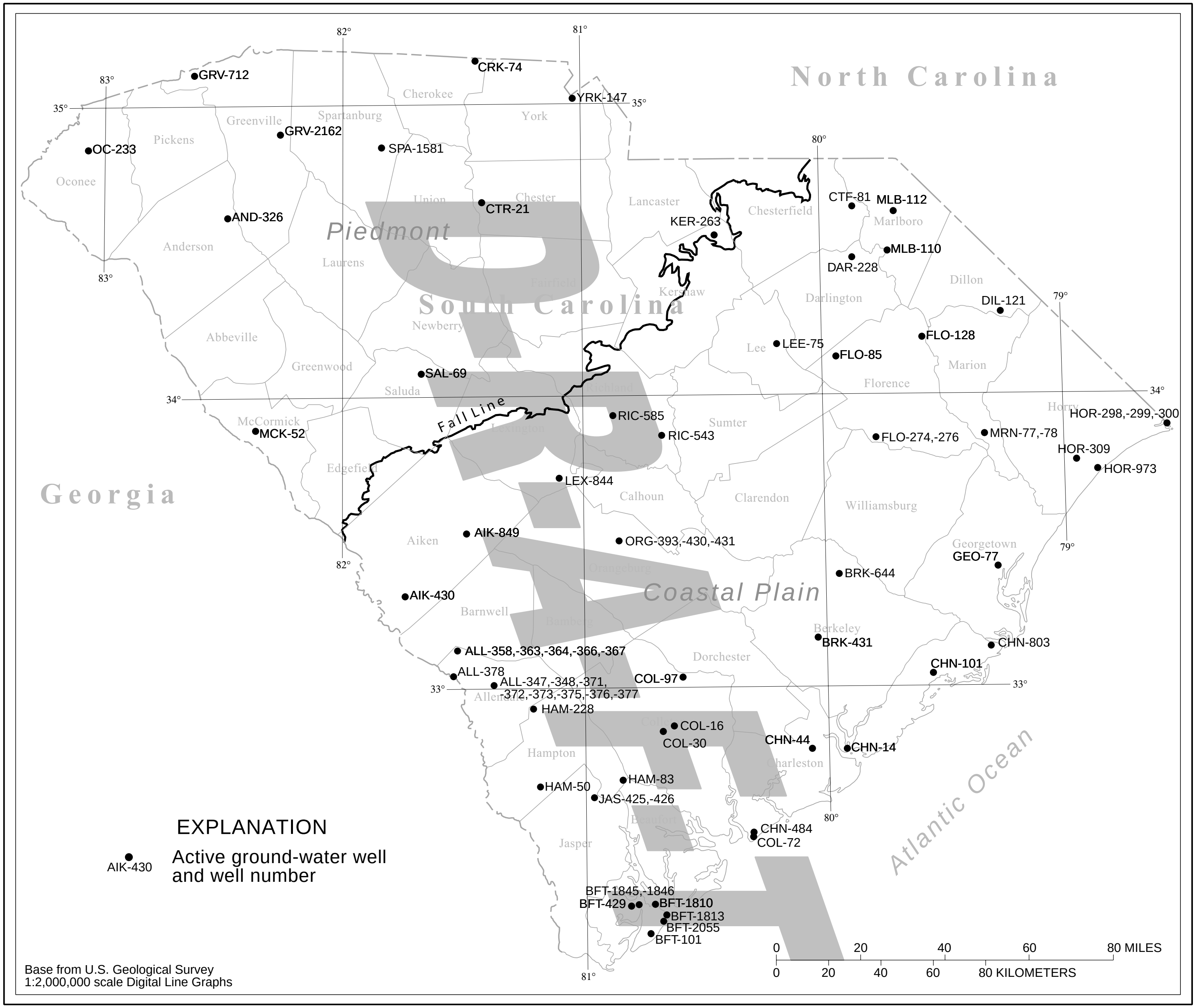


Figure 22. Current network of ground-water monitoring wells in South Carolina.

Table 4. **Number of existing and required monitoring wells for the confined aquifers of the Coastal Plain and the bedrock aquifers of the Piedmont**

County	Number of aquifers	Number of existing monitoring wells	Total number of monitoring wells required	Number of additional monitoring wells required
Abbeville	1	0	1	1
Aiken	3	2	6	4
Allendale	5	14	10	0
Anderson	1	1	1	0
Bamberg	5	0	10	10
Barnwell	4	0	8	8
Beaufort	4	7	8	4
Berkeley	5	2	10	8
Calhoun	4	0	8	8
Charleston	4	5	8	5
Cherokee	1	1	1	0
Chester	1	1	1	0
Chesterfield	3	1	5	4
Clarendon	4	0	8	8
Colleton	6	4	12	8
Darlington	2	1	4	3
Dillon	3	1	6	5
Dorchester	5	0	10	10
Edgefield	2	0	3	3
Fairfield	1	0	1	1
Florence	3	4	6	2
Georgetown	4	0	8	8
Greenville	1	2	1	0
Greenwood	1	0	1	1
Hampton	5	3	10	7
Horry	3	5	6	1
Jasper	5	1	10	9
Kershaw	3	1	5	4
Lancaster	1	0	1	1
Laurens	1	0	1	1
Lee	3	1	6	5
Lexington	3	1	6	5
McCormick	1	1	1	0
Marion	3	2	6	4
Marlboro	2	2	4	2
Newberry	1	0	1	1
Oconee	1	1	1	0
Orangeburg	5	3	10	7
Pickens	1	0	1	1
Richland	3	2	6	4
Saluda	1	1	1	0
Spartanburg	1	1	1	0
Sumter	3	0	6	6
Union	1	0	1	1
Williamsburg	5	0	10	10
York	1	1	1	0
Statewide	---	**72**	**232**	**170**

conditions, and thus serve as important indices for evaluating the severity of agricultural and hydrologic droughts. Water levels in unconfined aquifers can also be used to estimate the soil moisture content needed for flood magnitude predictions.

Movement of water within the water-table aquifers is strongly influenced by topography. As such, the location and number of monitoring wells should be based on the location and size of the sub-basins within the State. Each sub-basin should have at least one well that monitors water levels of the water-table aquifer. Each well should be sited at a drainage divide and each should be equipped with an automatic data logger. No wells are currently available for continuously monitoring the water-table aquifers of the State. Figure 23 shows the proposed locations of monitoring stations for these aquifers in both the Coastal Plain and Piedmont provinces.

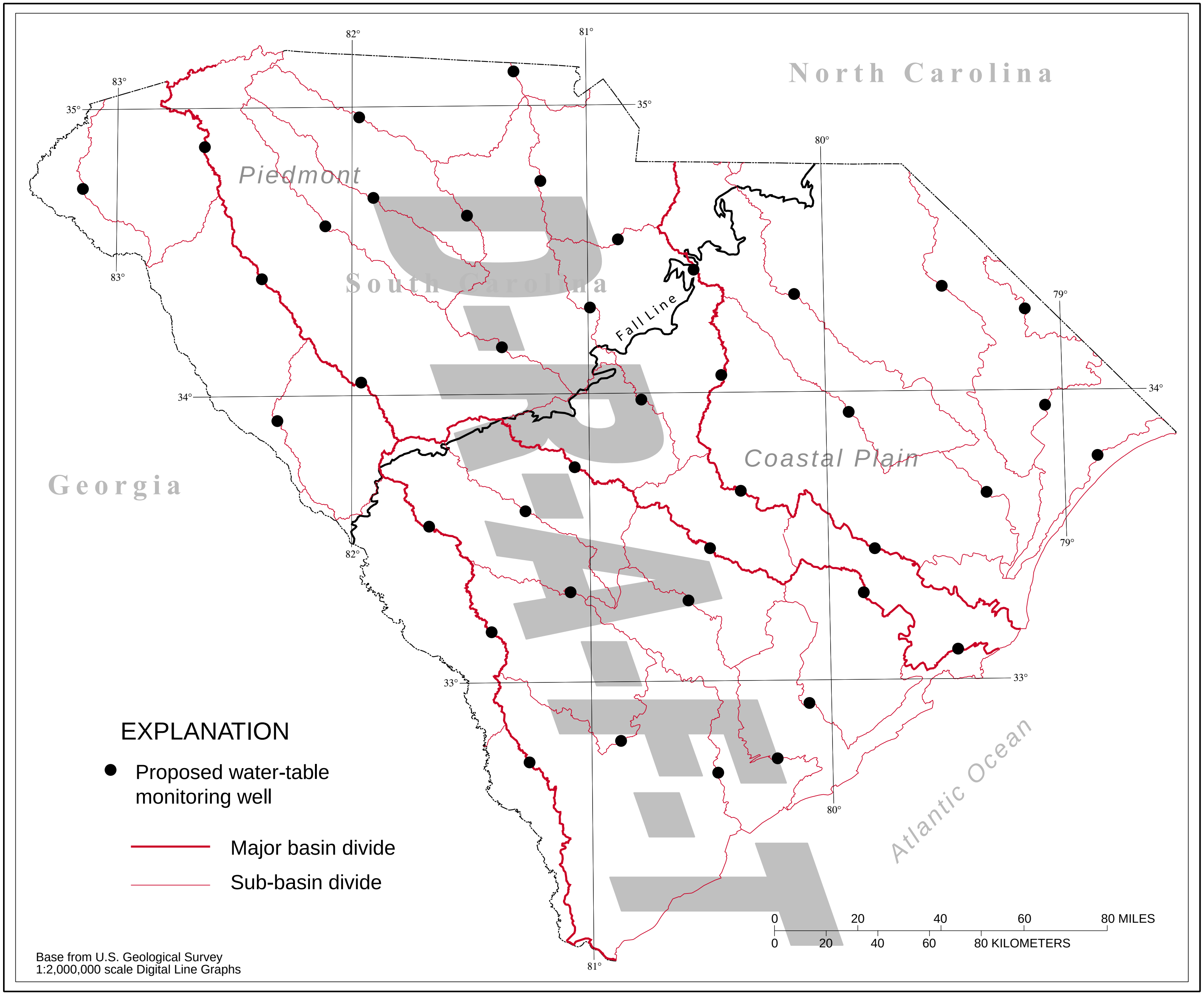


Figure 23. Proposed network of water-table monitoring wells in South Carolina.

GROUND WATER QUALITY

Like surface water, ground water is vulnerable to contamination and must be protected. Contrary to popular belief, sands and soils do not completely "filter out" all pollutants; even pathogens such as bacteria and viruses are found in ground water. This contamination occurs mainly from improper fuel storage and waste disposal, and from agricultural and industrial practices. Natural processes, however, can also degrade water quality. Elevated metal concentrations can result when metals, such as iron, are leached into ground water from minerals present in the earth.

Pollutants are numerous but commonly consist of nitrates, pathogens, petroleum products, metals, volatile organic compounds, fertilizers, pesticides, and radionuclides. In general, water-table aquifers are more susceptible to surface contamination than are confined aquifers, and therefore should not be used as potable sources without appropriate water-quality monitoring and analysis. Because shallow ground water and surface water are hydraulically connected, contaminated ground water that is discharging into surface waters can also degrade the water in streams, lakes, and wetlands.

Contamination can originate from point sources and form well-defined, localized plumes beneath leaking tanks or industrial spills, or it can occur over wide areas from diffuse, nonpoint sources such as from the improper application of fertilizers and pesticides or from urban runoff. Remediation of ground water is costly, time consuming, and is often ineffective at completely restoring water to its original condition. Consequently, efforts must be focused on preventing ground water contamination rather than on treating the problem after-the-fact. Ground water moves slowly, on the order of several feet per week, so it can take years before contaminants are detected. As such, all known sources of ground water contamination and those that can potentially pollute ground water must be controlled with a comprehensive management strategy that includes an effective monitoring system.

Water Quality Standards

Water quality standards promulgated in S.C. Regulation 61-68 (Water Classification and Standards) are applicable for both surface waters and ground waters. Because most of the ground water in the State "is presently suitable for drinking water without treatment … all South Carolina ground water is classified Class GB effective June 28, 1985," unless otherwise classified (S.C. Regulation 61-68, Water Classification and Standards). Class GB is ground water that is suitable for drinking and meets safe drinking water standards set forth in S.C. Regulation 61-58 (State Drinking Water Regulations).

The State recognizes that Class GB may not be suitable for some ground water. Ground water can also be classified as Class GA, which are exceptionally valuable ground waters that are vulnerable to contamination due to hydrological characteristics, or Class GC, which are ground waters not suitable for drinking. All ground waters must be "protected to a quality consistent with the use associated with classes" as defined above. The State has the right to require that an owner or operator of a contaminated site restore the ground water quality to a level that maintains and supports the classified use.

Pollution Control Programs

Federal, State, and local government agencies are responsible for enacting laws and regulations that protect ground water resources, but it is the responsibility of each citizen to do his part. The State's goal is "to maintain or restore ground water quality so it is suitable as a drinking water source without any treatment" (S.C. Regulation 61-68). DHEC administers most of the programs involving ground water quality, including the Clean Water Act and the Safe Drinking Water Act (SDWA). Section 102 of the Clean Water Act authorizes states to "develop comprehensive programs for preventing, reducing, or eliminating the pollution of navigable waters and ground waters and improving the sanitary condition of surface and underground waters." Under this authority, South Carolina is currently developing a Comprehensive State Ground Water Protection Program that will provide a framework for protecting the ground water resources.

The SDWA of 1974 protects public health by regulating public drinking water supplies. One of the most effective ways to ensure safe drinking water is to protect the source of the water. Source water protection is achieved through four programs provided under the SDWA: the Wellhead Protection Program, the Sole Source Aquifer Program, the Underground Injection Control Program, and the Source Water Assessment Program.

The Wellhead Protection Program is voluntary and allows for increased protection of source areas that supply water to public supply wells. Potential sources of contamination that threaten the wells are identified and the water system's susceptibility to each source of contamination is quantified. Amendments to the SDWA in 1996 essentially expanded this program to include surface water supply systems as well as ground water systems.

Under provisions of the Sole Source Aquifer Program, communities or individuals can petition the EPA for an added degree of protection for an aquifer that is the "sole or principal" source of drinking water for the community. A region is eligible to participate in this program if 50 percent or more of the population in the defined area relies on the designated aquifer as a source of drinking water. If the sole source aquifer is threatened by a project that is financed by the federal government, the EPA can modify the project to reduce the potential for contamination.

The Underground Injection Control Program regulates injection wells to ensure that they do not contaminate aquifers. Injection wells used to inject municipal and industrial wastes, and to dispose of hazardous or radioactive waste are prohibited in the State. The majority of injection wells permitted in the State are used for aquifer remediation.

The Resource Conservation and Recovery Act regulates monitoring, investigation, and remediation activities at currently operating hazardous treatment, storage, and disposal facilities. Underground storage tanks are regulated under this act. Storage tanks that leak gasoline are the leading cause of ground water pollution in the State.

The Comprehensive Environmental Response, Compensation, and Liability Act provides a federal "Superfund" to clean-up soil and ground water contaminated by uncontrolled and abandoned hazardous waste sites, or by accidents, spills, and other emergency releases of contaminants into the ground. Sites typically include industrial and municipal landfills and dump sites at military installations and manufacturing plants.

The Federal Insecticide, Fungicide, and Rodenticide Act protects human health and the environment by requiring the testing and registration of all chemicals used as active ingredients of pesticides and pesticide products.

Saltwater contamination of ground water is a concern in coastal counties of South Carolina. Over-pumping can induce saltwater into freshwater aquifers, contaminating the aquifers for years or even decades. The Groundwater Use and Reporting Act allows for areas threatened by over-pumping to be designated as Capacity Use Areas. In these areas, ground water withdrawals are regulated by the State, either by limiting the amount of water that can be pumped from a well or by limiting the number of wells that can be drilled into a specific aquifer. This act allows the State to minimize damages caused by saltwater contamination. Currently, all coastal counties in the State are designated as Capacity Use Areas.

Ground Water Quality Monitoring Networks

The State's ambient ground water quality monitoring network, operated by DHEC, consists of 115 wells located throughout the State (Figure 24). The objectives of this monitoring program are to determine the baseline values of ground water quality, to determine geographic and temporal variations in ground water quality, and to provide ground water quality data for specific aquifers, especially those that are in the initial phases of contamination studies.

Public wells constitute the majority of the wells in this network; however, in rural areas where public wells do not exist, privately owned wells are used. Wells are sampled in one or two of the major river basins each year and then are re-sampled on a five-year rotating cycle. This sampling schedule corresponds to the watershed water quality management schedule for surface water sampling. As such, both surface and ground water are sampled from the same watershed in the same year.

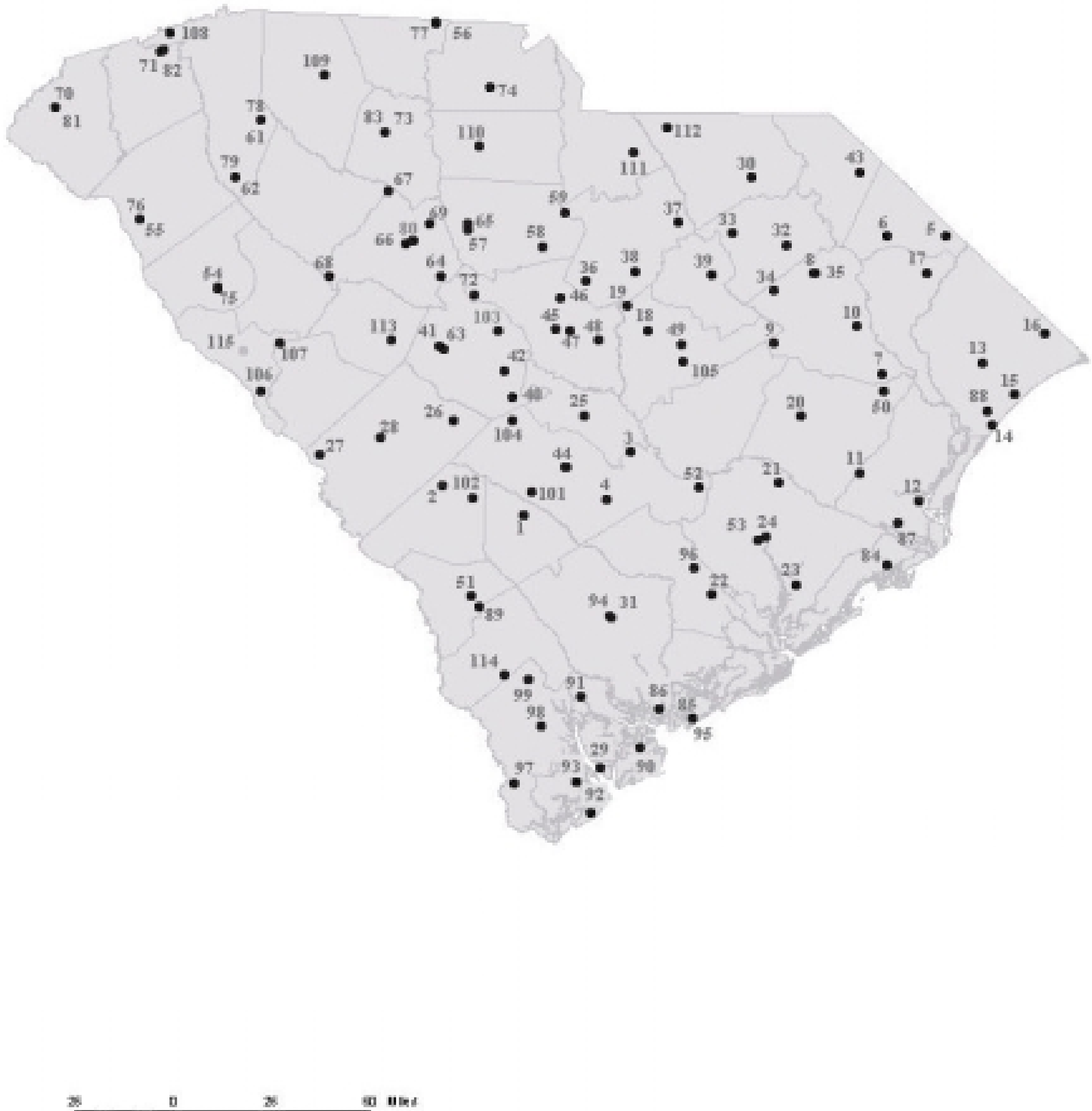


Figure 24. Location of wells in DHEC's Ambient Ground Water Quality Monitoring Network.

Other State and Federal agencies, such as the DNR and the U.S. Geological Survey, measure ground water quality for investigations related to specific study areas or to specific aquifers.

Saltwater Intrusion Monitoring Network

Some wells in coastal counties are already being continuously checked for specific conductance (a measure of salinity) to monitor saltwater intrusion, but saltwater intrusion and encroachment should be monitored in aquifers along the entire coast with automated recording devices. Well-cluster sites in six coastal zones should be constructed, each consisting of 3-4 wells (one per aquifer) that monitor electrical conductivity and water chemistry for saltwater contamination. Each major aquifer should have at least two monitoring wells equipped with automated recorders that measure specific conductance and chloride concentrations. Changes in conductance or chemistry within a well or changes between wells should be examined as an indication of possible saltwater intrusion and encroachment. In areas where saltwater problems are known to exist, more monitoring wells may be needed. Existing wells in the saltwater contamination monitoring network and proposed cluster sites are shown on Figure 25.

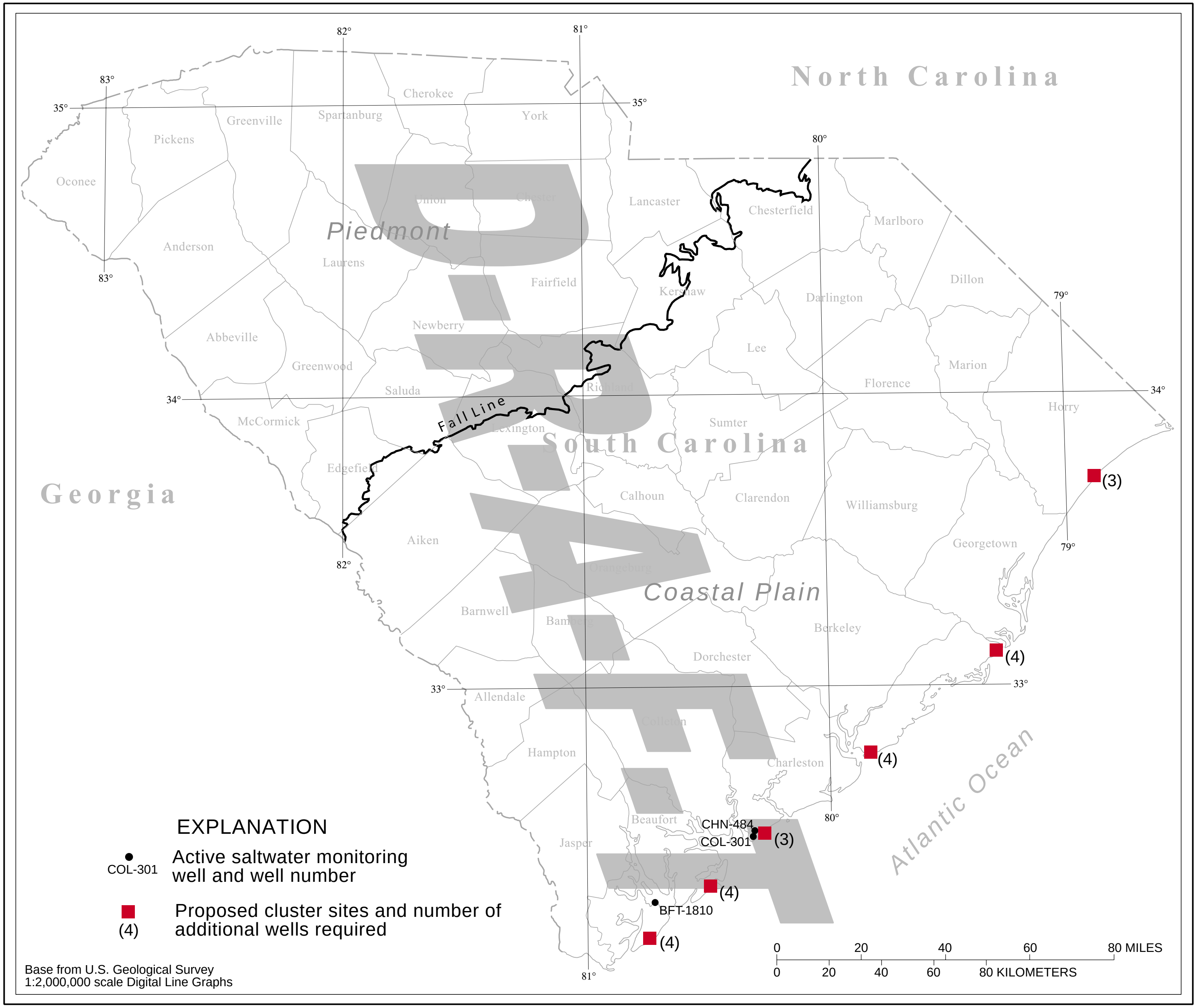


Figure 25. Location of saltwater intrusion and encroachment monitoring wells.

DROUGHT MANAGEMENT AND MITIGATION

Reduced precipitation for extended periods can cause an agricultural drought during the growing season and a lack of water to meet other demands. The State should have a statewide drought management and mitigation plan to help sustain all water uses in the State during water shortage periods. The available water during dry periods should be allocated among all uses in such a way as to minimize adverse economic and health-related problems, but all users within the drought-affected area should share the pain.

The Drought Response Committee was established by the South Carolina Drought Response Act of 1985 and includes State and local representation. The Committee has the authority to declare a drought based on climatic conditions, soil moisture, streamflows, and water levels in lakes and aquifers. The specific drought indices used in declaring a drought, and the corresponding drought levels, are the responsibility of the Drought Response Committee. The Committee may request that State and Federal water resource agencies provide additional monitoring of streamflows, water levels, and water quality to ascertain the adequacy of drought mitigation practices. The DNR serves as the primary agency to monitor drought conditions throughout the State and coordinate the State's response.

An updated status of soil moisture, streamflows, aquifer water levels, lake levels, and overall climate must be issued periodically for as long as the drought exists. Notification of water shortage conditions is to be provided by the DNR by letter and/or public communications through such media as newspaper, radio, television, and the Internet. The Drought Response Committee can recommend that the Governor issue a public statement imposing mandatory water-use restrictions. Economic, social, and environmental considerations should be used to help prioritize water use in order to enhance the recommendations of the Drought Response Committee and the Governor's Office.

A proactive approach to drought management is required to lessen the economic, social, and environmental impacts of drought. Federal and State funds should be used for drought mitigation, and cooperation among Federal, State, and local agencies, as well as private interests, is essential for sustaining all uses during dry periods. An assessment is needed of how droughts impact the State and of how vulnerability to droughts can be reduced. The following recommendations should be considered for inclusion into a drought mitigation plan:

- DHEC and DNR should develop allocation mechanisms for surface and ground water to ensure water availability and minimize conflicts during water shortages.

- DHEC and DNR should establish and enforce minimum required flows and water levels to protect water quality for the designated uses of surface water.

- Resource agencies should promote measures to increase water availability, as described in the "Maximizing Water Availability" section later in this report.

- Farmers should invest, with Federal and State support, in efficient irrigation systems if adequate surface or ground water supplies are available.

- Farmers, especially those not using irrigation systems, should select varieties of crops that have a high tolerance for dry weather.

- Federal and State resource agencies should implement research and programs to increase the accuracy of drought predictions. Earlier warnings will enhance drought management and mitigation.

- A statewide shallow ground water monitoring network should be developed to monitor the effects of drought on water-table aquifers.

- Statistical analyses of water-level data should be made from long-term surface and ground water records to determine the relative severity and recurrence interrval of droughts.

- All water suppliers should prepare drought response plans , specifying water reduction schedules, alternate supply sources, and backup systems.

- Major field crops can already be covered by the Federal crop insurance program, a feature of U.S. agricultural policy for decades. Other crops, livestock, and water-related small businesses (such as marinas) should also be covered under this Federal insurance program.

- Victims of drought should seek relief from the nearly 50 federal programs that have some element of drought relief, primarily for agricultural droughts. Also, the Emergency Board of each county in the State should help alleviate the impacts of extreme droughts on farmers, ranchers, local businesses, and communities.

- During the 1998-2002 drought, many owners of private wells had to deepen their wells or lower their pumps in reaction to water-level declines caused by the drought. No State or Federal assistance was available to help these citizens maintain their water supply. A program should be developed to provide financial assistance to low-income households in order to help them maintain their wells during prolonged or severe droughts.

FLOODPLAIN MANAGEMENT AND MITIGATION

The ancient Egyptians built their agriculture and social system around periodic flooding. Although floods are natural events necessary for healthy ecosystems, modern man tends to regard floods as natural disasters to be prevented if at all possible. Since the 1930's, the approach to flood control has been to build reservoirs capable of holding large volumes of water, while also building levees to prevent high streamflows from escaping the river channel. While this structural approach has been successful in reducing some flooding and flood damage, it has become very expensive, and does not guarantee protection: levees and floodwalls can fail or be overwhelmed by storms that exceed the design limits of the protective structures.

Because floodplains and wetlands provide important ecological and hydrological functions, an important goal of a floodplain management program should be to preserve natural floodplains, not only by limiting development in those areas, but also by allowing flooding to occur. The goal of floodplain management is not necessarily to reduce or eliminate flooding, but to reduce or eliminate the dangers and damages associated with floods. Floodplain management is most effective at the local level, but requires the cooperation of all levels of government, as well as those at risk from flooding.

Flood damage can be reduced by minimizing the potential for damage. Highly vulnerable structures and critical facilities, as well as large population groups, should be relocated out of potential flood areas. Levees and floodwalls can protect heavily developed areas, but these structures are expensive and provide a false sense of security. Because all developments have the potential to increase flood damage by increasing flood stage, flood flow, and flood velocity, or by altering erosion rates, new developments can increase the flood risk for existing structures previously thought to be adequately protected. It is important that new developments are designed to minimize any flood impact they may have on existing structures.

With the goal of protecting the public and minimizing flood damages, the South Carolina DNR developed the *South Carolina Flood Mitigation Plan* in September 1999. Both State and Federal governments should encourage and provide incentives for communities that participate in flood management planning while discouraging behavior likely to result in future loss of property and life. The State should also oversee floodplain and floodway delineation, and verify the hydrologic and hydraulic analyses used to make those delineations. Because the DNR administers the National Flood Insurance Program, the Flood Mitigation Program, and FEMA's Map Modernization Program for South Carolina, it should be the State agency spearheading the implementation of these management and mitigation practices.

BASIN-WIDE MANAGEMENT AND INTERSTATE COOPERATION

Conflicting jurisdictions, authorities, and program objectives of the various government agencies and private organizations that have interests in the water resources of a basin greatly compound the complexity of effective water resources management. The State should establish a "river basin commission" for each of its four major basins. Each commission, made up of representatives from Federal, State, and local agencies and stakeholders, would integrate water planning programs, funding, and decision-making under one umbrella, providing a basin-wide comprehensive water resources plan to optimize water use throughout that basin.

The water in three of the four major basins in South Carolina is shared with either Georgia or North Carolina. To promote interstate coordination and reduce potential disputes between these States, formal mechanisms meant to provide equitable water apportionment, such as river basin commissions, interstate compacts, memoranda of agreement, or protocols, should be developed between these States. These mechanisms also provide the means for active programs for basin-wide water conservation, flood protection, improved water quality, dependable navigation, and protection of fish and wildlife habitats.

DNR, DHEC, other State resource agencies, the State Legislature, and the Governor must work together with their counterparts in Georgia and North Carolina to develop these formal mechanisms. The United States government, including the Corps of Engineers and FERC, should be involved in developing these mechanisms, whenever appropriate.

MAXIMIZING WATER AVAILABILITY

South Carolina ordinarily receives ample water to meet its present and future needs, but because of its temporal and spatial distribution, water is sometimes unavailable in the right place at the right time and of the right quality. This variability in the water supply is controlled to a large extent by climatic factors over which man has no influence. Water shortages, droughts, and increasing populations are driving nations, states, and municipalities to investigate better ways of conserving water and to find new and alternative water supply technologies. South Carolina needs to join this quest for a sustainable water supply.

Consideration must be given to resource management policies that can help maximize water availability. The DNR, in cooperation with other government and private agencies, should investigate the economic feasibilty and overall practicality of the following practices, and encourage their implementation where appropriate.

1. Water conservation
2. Optimization of water use in reservoirs
3. Construction of new reservoirs
4. Agricultural water table management
5. Aquifer storage and recovery
6. Interbasin transfer of water
7. Conjunctive water use
8. Desalination
9. Gray water
10. Recycled wastewater

Water Conservation

Water conservation and improved efficiency of use can have many benefits and should be the first approach for extending or augmenting available supplies. However, conservation has a limited impact on the overall water supply unless the consumptive use is reduced. Conservation can significantly extend water supply availability and can also reduce costs to municipal facilities.

Water conservation must become an integral component of effective water resource management. Water should be conserved at all times rather than only as a last resort during times of crisis. Initiatives to manage water resources effectively can only be achieved through cooperation and collaboration among all water users—individuals, businesses, industries, farmers, and government. Individuals must conserve water at home and at work. Businesses and industries across the State must find more efficient ways to use water and eliminate waste. Farmers must help find solutions that reduce their irrigation needs while protecting their crops. And all water supply systems must develop interconnections with neighboring systems, increase storage capacity when possible, and establish aggressive conservation programs.

Water conservation can be achieved through more efficient operation of storage and delivery facilities (to increase supply) and more efficient use by users (to reduce demand). Implementation of many conservation measures will present new challenges in securing authorizing legislation and funding, developing integrated policies, setting an appropriate balance of government and the private sector, and integrating research and education for technology transfer.

The key to making water conservation work is education. Significant water use reductions can be achieved when people understand the reasons to conserve. South Carolina needs a multifaceted water conservation campaign with voluntary, incentive, and regulatory mechanisms to address both supply-side and demand-side conservation.

Optimization of Water Use in Reservoirs

The State should play a major role in managing existing reservoirs to allocate water and minimize any conflicts between all upstream, downstream, and lake uses. All uses, including, but not limited to, water supplies, hydroelectric power, fish and wildlife, water quality, recreation, flood control, and real estate, are equally important. During water shortages, all users should share the burden.

Each reservoir should have a drought contingency plan that associates reservoir water levels, drought conditions, and natural inflows to the allocation of water for all uses, including downstream releases. These plans should be developed in coordination with State resource agencies, federal agencies, stakeholders, and all interested parties in the basin. The drought contingency plan should minimize the likelihood of a reservoir's conservation pool becoming so depleted that no more water is available for withdrawal for public supplies. State resource agencies should take an active role in developing and enforcing these plans to maximize water supplies for all uses.

Construction of New Reservoirs

Although there is usually more than enough water in South Carolina to satisfy all the demands for it, shortages can occur when water availability is low. One method for improving water availability is to capture excess water during wet periods and store it in reservoirs for use during dry periods. Water stored in reservoirs in South Carolina and its neighboring states played a major role in alleviating the drought of 1998-2002; very low natural flows in the streams were supplemented by releases of water stored in those reservoirs.

Instream Reservoirs

There are two main types of reservoirs: instream and offstream. Instream reservoirs are built by damming streams to store water captured during periods of high flow. The reservoir changes the natural flow of a stream, reduces flooding, provides water for generation of hydroelectric power and other uses, and can augment the streamflow below the dam during low-flow periods. When instream reservoirs are constructed, stream and wetland ecosystems are altered in the reservoir area, upstream from the reservoir, and downstream from the dam. Because instream reservoirs tend to reduce downstream flooding, floodplain wetlands adjacent to streams receive less water and often undergo significant ecosystem changes. The migration of fish and other aquatic organisms across dams decreases or ceases, altering ecosystems both above and below the dam. There may be a gain or loss in the diversity of organisms. Vegetation in a lake is different from vegetation in streams, and terrestrial and wetland wildlife habitats are converted to open-water habitats. Instream reservoirs also serve as traps for sediment and nutrients, and while nutrient concentrations may be greater in the reservoir than downstream, dissolved oxygen levels are often much lower in reservoirs than in flowing streams. Recreational opportunities for reservoirs and those for free-flowing streams are different, and use of the reservoir is dependent upon ownership and provision for public access to the reservoir.

Offstream Reservoirs

Offstream reservoirs are built adjacent to streams to store water captured during periods of high flow. The reservoir modifies the natural flow of a stream: water storage can lessen flooding, provide water for other uses such as generation of electricity, and augment low streamflow downstream from the reservoir, but because of increased evaporation, the overall flow volume in the system usually decreases. The ecosystem downstream of the reservoir is likely to be modified (because of changes in the flow rates, volumes, and patterns), and a new reservoir ecosystem is added. There is often a gain in the diversity of aquatic organisms, since terrestrial habitat is replaced by aquatic habitat. Recreational use of the stream is generally not significantly changed. Use of the reservoir is dependent upon ownership and provision for public access to the reservoir.

Agricultural Water Table Management

Agricultural water table management is the management, control, and regulation of soil-water conditions in the profile of agricultural soils: excess and deficit soil-water conditions can be managed to provide better plant growth conditions, with the benefit of more efficient water use. Agricultural water table management also provides an added level of protection to farmers from drought conditions by artificially maintaining the water content in the soil and reducing water loss through drainage. The key elements of effective water table management are controlled subsurface drainage and subirrigation.

The addition of properly designed and constructed water-control structures to a subsurface drainage system allows the drainage outlet to be artificially set at any level between the ground surface and the drain depth. Raising the outlet after planting helps keep water available for plant use longer than does uncontrolled subsurface drainage. This practice also can be used to recharge the water table between growing seasons by capturing water that would normally drain into local streams.

With subirrigation, water is supplied through the subsurface drainage system using control structures to regulate the water table level in the field. Irrigation water is applied below the ground surface, thus raising and maintaining a water table at an appropriate depth in the crop root zone. The pumping system and water control structure can be managed to create a constant water table depth or a fluctuating water table. If the system is properly designed for the site and soil conditions, loss of water through deep seepage is negligible, and runoff of irrigation water rarely occurs. Water is always applied where the crop needs it most. A water supply such as a deep well, farm pond, or stream, can be used to supply adequate supplemental water when needed for subirrigation.

Together with the U.S. Department of Agriculture's South Carolina Natural Resources Conservation Service and other agricultural research institutes, the DNR should promote these techniques and provide design and operational guidance and, if possible, financial incentives to farmers implementing these practices.

Aquifer Storage and Recovery

Underground water storage involves the injection or infiltration of water into an aquifer for future use. In effect, it makes use of an underground reservoir to store water in much the same way that surface water reservoirs are used. This technique has advantages over storage in surface water reservoirs because water stored underground is not subject to evaporation and is less easily contaminated. Artificial aquifer recharge holds significant potential for the storage of surplus, good-quality water for future use.

Aquifer storage and recovery (ASR) projects take advantage of a water supplier's unused treatment capacity during times of low water demand (usually in the winter) to treat surface water and then pump it into an aquifer for storage until later recovery during times of peak demand or low flow (typically a few days during the summer). ASR helps water suppliers meet peak summer demands by providing pretreated water to augment surface supplies without the need for increased treatment capacity.

ASR programs are already in use throughout the United States. In South Carolina, ASR programs are operating in Horry, Charleston, Beaufort, and Jasper Counties. An ASR program is being considered in Orangeburg County, and the South Carolina DNR is currently studying the feasibility of using ASR techniques in the Piedmont province.

Interbasin Transfer of Water

In some areas, the demand for water may exceed the natural availability, resulting in a water shortage. One solution to this problem is to transfer water from an area that has an excess of water into the area that has the deficit. The interbasin transfer of water involves moving water from one hydrologic basin (the origin basin) into another basin (the receipt basin), where it is used and discharged. The significant feature of interbasin transfer is that the water is completely removed from the origin basin, preventing its use by anyone downstream of the withdrawal point.

The Interbasin Transfer Act of 1985 gave DHEC the authority to regulate and permit interbasin transfers in South Carolina. Permit conditions should reflect a scientific understanding of the water availability, and protect both basins of origin and receipt. Interbasin transfer permit conditions should also consider the flow frequency and magnitude of the source stream, as well as the volume of stored water needed to supplement natural low flows in the origin basin.

Normally, there will be enough water in the origin basin so that transferring water to another basin will not result in detrimental water shortages within the origin basin. If the origin basin is experiencing a water shortage, however, there may not be enough water available for transfer without aggravating the water shortage in the origin basin. A trigger mechanism should be designed into special permit conditions to make transferable volumes proportional to the available water volume in the origin basin: the less water available, the less water transferred. In that way, both the origin and receipt basins share the burden during water shortages.

Conjunctive Water Use

Conjunctive water use is the combined use of ground- and surface-water resources in order to optimize the water availability, increase the reliability of the water supply, or to offset the negative impacts of using a single source. Water planners should consider the implementation of conjunctive strategies—that is, using both surface water and ground water—for the following conditions:

- If withdrawals from a single source are limited or are unreliable;
- If heavy withdrawals from aquifers are substantially altering horizontal or vertical flow patterns or are causing land subsidence or irreversible damage to the aquifers;
- If withdrawals from aquifers are negatively impacting domestic ground-water users;
- If withdrawals from streams are destructive to aquatic ecosystems;
- If water quality from a single source is inconsistent or undesirable.

The combined use of ground water and surface water should be optimized to reduce the effects that withdrawals have on either source and on the environment.

Desalination Desalination is the process in which dissolved minerals—primarily salt—are removed from seawater or brackish water, making the saltwater or brackish water suitable for use in public supply systems. Desalination plants are becoming increasingly common, primarily in high-growth coastal areas of Florida and California. While only Florida is currently desalting seawater for drinking water use, over 20 states employ technologies such as reverse osmosis to desalt brackish water (Movahed, 2002). South Carolina is one of those states using reverse osmosis: in 1991, Mount Pleasant Waterworks became the first municipal water system in South Carolina to provide drinking water treated using reverse osmosis technology.

The most common objection to using desalted water to help meet municipal water needs is that the process is too expensive. However, developments in technology and improvements in desalting processes have dramatically reduced the cost of desalination over the past 30 years. When considering new sources for public supplies near the coast, State and local governments, as well as private water companies, should consider the feasibility of desalination by making cost comparisons to other sources of suitable water, such as surface water impoundments, remote well fields, and long distance pipelines.

Gray Water Gray water is water that can be used twice; it includes the discharge from kitchen sinks and dishwashers (*not* garbage disposals); bathtubs, showers and lavatories (*not* toilets); and household laundry (*not* diaper water). Using gray water can almost double home water-use efficiency and provide a water source for landscape irrigation. Although properly treated and continuously-monitored gray water can be a valuable and safe resource for landscape irrigation, poor maintenance or system neglect can lead to human health problems and maintenance difficulties. Currently, South Carolina's health codes do not allow the reuse of gray water because of possible health risks.

Recycled Wastewater

Treated municipal wastewater can be recycled for irrigation, industry, and fire-control purposes. The use of reclaimed water is less expensive, optimizes the resource, provides nutrients to crops, reduces surface-water pollution, and conserves freshwater. However, because effluent can contain pathogens and harmful chemicals, it must be carefully applied and monitored in order to prevent direct human contact and contamination of ground-water resources. Only effluent that has passed through a secondary treatment phase and that has been approved by public health officials should be recycled. A separate delivery system must be constructed to prevent contamination to the public-water system. If effluent is used for irrigation, monitor wells should be constructed to evaluate the long-term effects on ground-water quality. Effluent irrigation should not be used on row crops or crops that are eaten raw, such as fruits and nuts, but can be used on grasslands such as turf farms, pastures, golf courses, parks, athletic fields, and cemeteries. The State encourages the use of recycled water as long as it is adequately treated to ensure water quality appropriate for the use.

RECOMMENDATIONS

WATER RESOURCES MANAGEMENT

The effective management of South Carolina's water resources is beyond the scope of any one agency or organization, and will require cooperation and shared responsibility among Federal, State and local agencies, as well as public and private parties.

Management strategies must be flexible, responsive to trial, monitoring, and feedback, and should change in response to new scientific information and technical knowledge. This "adaptive management" approach provides a process for continually improving management practices and policies. Effective resource management requires the increased utilization of regulatory science.

Research institutes and universities should be encouraged to work with State resource agencies to advance regulatory science and become integrated into the decision-making processes of the State.

The State should establish a "river basin commission" for each of its four major basins. Each commission, made up of representatives from Federal, State, and local agencies and stakeholders, would integrate water planning programs, funding, and decision-making under one umbrella, providing a basin-wide comprehensive water resources plan to optimize water use throughout that basin. Formal mechanisms meant to provide equitable water apportionment, such as river basin commissions, interstate compacts, memoranda of agreement, or protocols, should be developed with Georgia and North Carolina.

Consideration must be given to resource management policies that can help maximize water availability. The State, in cooperation with other government and private agencies, should investigate the economic feasibility and overall practicality of these policies.

In order to effectively manage the State's water resources, comprehensive and accurate monitoring of water use is needed. Accurate estimates of ground and surface water use are still difficult to obtain.

Preventing and reducing water pollution is the collective responsibility of all levels of government, agriculture, industry, landowners, and citizens alike and is best achieved at the watershed level, by enhancing stewardship, forging partnerships, and increasing public education and participation.

Source Water Assessments should be used by public water systems to determine what preventive actions are needed to protect drinking water sources from contamination.

The State must remain committed to the protection and restoration of its wetlands and to the concept of no net loss of wetlands. Legislation should be enacted to establish a statewide wetlands protection program.

Water conservation and improved efficiency of use can have many benefits and should be the first approach for extending or augmenting available supplies. Water should be conserved at all times rather than only as a last resort during times of crisis. South Carolina needs a multifaceted water conservation campaign with voluntary, incentive, and regulatory mechanisms to address both supply-side and demand-side conservation.

Water planners should consider the implementation of conjunctive strategies—that is, using both surface water and ground water. The combined use of ground water and surface water should be optimized to reduce the effects that withdrawals have on either source and on the environment.

All water supply systems should develop interconnections with neighboring systems, increase storage capacity when needed, and establish aggressive conservation programs.

The State should promote efficient irrigation and agricultural water table management techniques and provide design and operational guidance and, if possible, financial incentives to farmers implementing these practices.

Interbasin transfer permits should allow for restrictions on the volume of transferable water during water shortages in the origin basin.

Water suppliers near the coast should consider the technical and economic feasibility of desalination as a source of water.

Treated municipal wastewater should be recycled for irrigation use on grasslands such as turf farms, pastures, parks, athletic fields, and golf courses.

SURFACE WATER

The effective management of the State's surface water system requires a coordinated management of its lakes and rivers in order to balance the needs of lake users with the needs of river users.

To maximize water availability at all times and to protect human and economic needs, surface water use must be regulated. An allocation mechanism must be established to control the distribution of water so that all users have a reliable water supply. Variations in surface water availability and the location of demands must play major roles in the water allocation.

Desired and minimum required flows for streams should be established to protect public health and safety, maintain fish and wildlife, and provide recreation and navigation while promoting aesthetic and ecological values. It is the responsibility of the DNR to determine the minimum flow required to protect the State's aquatic resources.

The DNR should evaluate each regulated river in the State to determine the desired and minimum required flows just downstream from each reservoir.

The State should determine the minimum streamflow needed to maintain ecological functions of estuaries and to prevent saltwater contamination of water supply intakes.

The volume of permitted discharges should be adjusted as needed to reflect variability in the assimilative capacity of a river, which will change over time due to the natural cyclicity of wet and dry periods.

Reservoir operations should be planned to ensure adequate instantaneous or average daily flows, rather than average weekly flows.

Releases from reservoirs should be conducted in such a way as to mimic natural seasonal fluctuations in streamflow, where appropriate.

During non-drought conditions, reservoirs should be operated so that releases are sufficient to ensure that desired downstream flows are always met. During droughts, the reservoir's drought contingency plan must be enforced.

Downstream minimum required flows can be achieved by incorporating the appropriate releases into the FERC licenses, State operating permit, or Corps of Engineers operating plan.

The State needs to be involved in the issuing and reissuing of FERC reservoir operating licenses, which offer excellent opportunities to incorporate strategies for managing the entire river system into the reservoir operating plans.

It is important that reservoir operating plans detailed in FERC licenses allow for some flexibility in reservoir operations so that resource managers can react to changes in either water availability or demands for water without having to wait for the next relicensing opportunity.

The State should continue to use its authority under Section 401 of the Federal Clean Water Act to ensure that any proposed releases will not result in violations of State water quality standards, or will not result in an unacceptable degradation of water quality.

Because Georgia and South Carolina share the Savannah River and its lakes, both States must work together to incorporate appropriate release schedules into the Corps of Engineers operating plans for these lakes.

State Legislatures should authorize the development of a formal agreement between the States of Georgia and South Carolina to work together to manage the Savannah River Basin.

South Carolina and Georgia should continue to support the *Savannah River Basin Comprehensive Water Resources Study*, an ongoing cooperative technical project between Georgia, South Carolina, and the Corps of Engineers.

State agencies should work with relevant Federal agencies in order to coordinate activities relating to the water resources of the State.

When lake levels are at or above the rule-curve elevation, water releases from the reservoir should equal or exceed the downstream desired flow requirements.

When lake levels fall to below the first water-shortage severity level because of low inflow, both downstream releases and offstream lake withdrawals should be reduced.

When lake levels fall to near the bottom of the conservation pool, and running out of water becomes a realistic concern, downstream releases should be set equal to the inflow into the lake. All regulated lakes must be studied to determine what specific lake levels will trigger this action.

Having an adequate number of properly located gages is vital to the effectiveness of the surface water monitoring network. The State should provide adequate funding to support this monitoring program and to prevent the loss of existing gages.

Protecting, improving, and restoring water quality are goals of the State. Waters that do not meet standards must be restored.

Continue to develop and improve water quality standards that will meet the goals of South Carolina and the Clean Water Act.

The State should continue to revise and refine water quality monitoring programs to address additional potential impacts to water quality from increasing population and development. Increase analytical capabilities to measure the presence of chemicals at very low concentrations. Strengthen monitoring programs that assess biological integrity of water bodies. Improve lake water-quality monitoring programs.

The State should continue to develop and implement Total Maximum Daily Loads for all waters on the 303(d) list. This includes waters impaired solely or primarily by NPS sources.

The State should continue efforts to reduce point source pollution by issuing water-quality based NPDES permits.

The State should continue to seek additional resources and technology to identify and reduce nonpoint sources of pollution.

The State should investigate the elevated mercury levels found in fish tissue samples.

The State should continue to investigate elevated levels of uranium and radium that have been found in some aquifers.

The State should continue to conduct water quality assessment and protection at the watershed level. Continue to increase watershed partnerships between government, the private sector, and stakeholders and encourage resource stewardship through education and outreach.

GROUND WATER

Advancing our knowledge of the State's ground water resources must continue with routine data collection, county and statewide ground water investigations, and with programs like the Surface Geophysics (WADI) and Borehole Geophysical Logging Programs.

To protect aquifer systems and to ensure the long-term sustainability of the ground water resources, the entire Coastal Plain province should be designated a Capacity Use Area.

Efforts should be coordinated between DHEC and DNR to ensure that geophysical logs are obtained from new public-supply wells in areas of the State where they are needed.

The State, in cooperation with the USGS, should reevaluate the existing hydrogeologic framework and improve it where necessary. New test holes should be drilled in areas that lack substantial subsurface data.

A comprehensive ground water flow model of the Coastal Plain should be developed cooperatively with the USGS.

Potentiometric maps of each major aquifer in the State should be constructed at least every five years to identify those areas where over-pumping is occurring and to determine how ground water levels are changing with time.

The DNR and USGS should be given 60 days advance notice of any well that is being considered for abandonment. If deemed important to the State's ground water monitoring programs, a variance should be granted to keep a well from being permanently plugged.

A study should be made by the State to determine if, and to what extent, subsidence has occurred in the Coastal Plain.

The Trigger Levels described in the 1998 *South Carolina Water Plan* should continue to be used as the maximum limit to which ground-water levels are allowed to decline before withdrawal restrictions are imposed. Studies should be made to refine these Trigger Levels throughout the Coastal Plain.

Resource managers should develop ground water policies—such as mandatory well spacing, or the declaration of certain aquifers as "domestic use only"—to minimize the need for restricted ground-water withdrawals. Withdrawals should be managed so as to minimize their impacts on other users of the aquifer. Large-capacity wells should be placed suitably far from existing domestic wells, and, if possible, they should not be screened or gravel-packed in aquifers used primarily for domestic supply.

Efforts must be focused on preventing ground water contamination as well as treating the problem after-the-fact.

Withdrawals should be managed so as to minimize degradation of aquifer water quality and to make the most efficient use of the water.

Withdrawals of water from an aquifer should not result in saltwater intrusion or encroachment. Withdrawal locations should be sufficiently inland so as not to exacerbate existing intrusion, but to aid in its elimination.

Withdrawal rates should be managed so as to prevent subsidence of the land surface and sinkholes at all locations.

Withdrawals from water-table aquifers should be managed with consideration for the impact these aquifers have on wetlands, floodplains, saltwater intrusion, surface water bodies, and confined aquifers.

Withdrawals from aquifers that have significant water-level declines should be restricted so as to minimize further declines or to reverse declines. Ground water flow models should be developed and used to predict the effect of future pumping and to determine optimal well spacings.

Withdrawals during droughts should be managed to protect drinking water supplies obtained from public supply wells or private domestic wells.

Ground-water quantity should be monitored in the Coastal Plain and Piedmont provinces to determine the overall effects that pumping and drought have on the State's ground-water resources.

In each county, water levels in a minimum of two wells per aquifer should be monitored with automatic data loggers. In those counties where water-level declines have been documented, or where a single aquifer is heavily utilized, a minimum of three wells should be monitored per aquifer.

Water levels in a minimum of one well per county should be monitored in the bedrock aquifers of the Piedmont province.

A statewide water-table monitoring network should be established. Each sub-basin should have at least one well that monitors water levels of the water-table aquifer. Each well should be sited at a drainage divide.

Saltwater intrusion and encroachment should be monitored in aquifers along the entire coast; each major aquifer should have at least two monitoring wells.

DROUGHT MANAGEMENT AND MITIGATION

The State should have a statewide drought management and mitigation plan to enhance current drought-related legislation and to help sustain all water uses in the State during water shortages.

Water available during dry periods should be allocated among all uses in such a way as to minimize adverse economic, environmental, and health-related problems, but all users within the drought-affected area should share the burden.

Drought contingency plans must be developed by lake owners for all Federally-operated, FERC-licensed, or State-permitted lakes in the State.

All water suppliers and industries should prepare drought response plans, specifying system-specific triggers or indicators, pre-drought planning efforts, water reduction schedules, alternate supply sources, and backup systems.

Economic, social, and environmental impacts should be considered when prioritizing water use.

Federal and State resource agencies should implement research and programs to increase the accuracy of drought predictions.

Farmers should invest in efficient irrigation systems if adequate surface or ground water supplies are available, and should select varieties of crops that have a high tolerance for dry weather.

Major field crops are covered by the Federal crop insurance program. Crop insurance, a feature of U.S. agricultural policy for decades, serves as a drought mitigation program. Other crops, livestock, and water-related small businesses (such as marinas) should also be covered under this Federal crop insurance program.

During the 1998-2002 drought, many owners of private wells had to deepen their wells or lower their pumps in reaction to water-level declines caused by the drought. No State or Federal assistance was available to help these citizens maintain their water supply. A program should be developed to provide financial assistance to low-income households.

FLOODPLAIN MANAGEMENT AND MITIGATION

An important goal of a floodplain management program should be to preserve natural floodplains, not only by limiting development in those areas, but also by allowing flooding to occur.

Highly vulnerable structures and critical facilities, as well as large population groups, should be relocated out of flood hazard areas.

New developments should be designed to minimize any flood impact they may have on existing structures.

State and Federal governments should encourage and provide incentives for communities that participate in flood management planning while discouraging behavior likely to result in future loss of property and life.

The State should oversee floodplain and floodway delineation, and verify the hydrologic and hydraulic analyses used to make those delineations.